

To the Graduate Council:

I am submitting herewith a dissertation written by William Dale Witherspoon entitled "Structure of Blue Ridge Thrust Front, Tennessee, Southern Appalachians." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geology.

Dietrich Roeder

Dietrich Roeder, Major Professor

We have read this dissertation  
and recommend its acceptance:

Karla C. Misra

Gred B. Keller

W. E. Needa

Accepted for the Council:

L. Evans Beth

Vice Chancellor  
Graduate Studies and Research

STRUCTURE OF BLUE RIDGE THRUST FRONT,  
TENNESSEE, SOUTHERN APPALACHIANS

A Dissertation  
Presented for the  
Doctor of Philosophy  
Degree  
The University of Tennessee, Knoxville

William Dale Witherspoon

June 1981

3056742



## ACKNOWLEDGMENTS

I would like to thank my committee members Kula Misra and W. E. Deeds, and particularly Fred Keller and Chairman Dietrich Roeder, who contributed some fruitful geologic discussions and field visits. H. Y. McSween also served on the committee at an early stage.

Financial support was provided by a Gulf Foundation Fellowship in the Geological Sciences, by a National Science Foundation grant to Dietrich Roeder, and by the Don Jones fund and Exxon fund of The University of Tennessee, Knoxville.

Fred Keller generously granted access to his unpublished Ph.D. dissertation (Yale University). Stephen Kish made available radiometric ages from his unpublished Master's thesis (Florida State University).

The 1978 Hatcher-Dallmeyer Penrose conference on thrusting stimulated research at an early stage, as did field trips in Tennessee and North Carolina with David Elliott and his students. James Sears first suggested to the writer the relationship between gravity data and palinspastic restoration of the Ocoee strata, and an interpretation and restoration of the COCORP profile by A. W. Bally stimulated the writer to formulate his own. Discussions with Robert Hatcher, Leonard Wiener, and Fred Cook also helped steer the research.

The National Park Service permitted collection of samples inside Great Smoky Mountains National Park. The University of Tennessee, Knoxville, Computing Center has been especially cooperative, both in work with the Tektronix devices and in allowing this work to be edited and typed on the Decsystem-10.

The Geosciences Department of The University of Tennessee, Chattanooga provided student help and drafting space during and after the writer's time there as instructor. I wish especially to thank William Black, head of the department, and Jeff Hertzing, student assistant.

Shell Development Company, Houston, Texas, has assisted in preparing the final draft. I particularly thank Ulyesses Louis, draftsman.

Finally, I would like to thank my parents, particularly for lending me their trailer and their mountain cabin during portions of the fieldwork.

## ABSTRACT

An interpretation of a COCORP seismic reflection profile indicates that the Great Smoky thrust, cropping out in southeast Tennessee, has a slip of about 140 km. Eight structure sections, drawn to the base of Paleozoic deformation, straddle the trace of the thrust and cover an area of about 12,000 square km. The sections show that the Great Smoky thrust cuts the most internal (southeasterly) structures of the Valley and Ridge thrust system, but was in place prior to movement of the Saltville fault in that system.

The sections suggest that several thrusts internal to the Great Smoky fault (Miller Cove, Dunn Creek, Brushy Mountain, and others) belong to a sledrunner thrust complex (COCORP thrust system) similar to the Valley and Ridge. The basal detachment in this complex was the Great Smoky fault, and, in northeast Tennessee, the Pulaski fault.

The COCORP thrust system differs from the more external Valley and Ridge thrust system in that it dismembers structures formed by polyphase, at least partly early Paleozoic, deformation. Pre-, syn-, and post-foliation structures are cut obliquely (map view) and discordantly (cross section) by elements of the COCORP thrust system along its external limit of outcrop.

In the internal portion of the western Blue Ridge, relations of folds to COCORP thrusting are poorly documented, but several tectonic events are broadly synchronous with regional metamorphism. In particular, the Greenbrier fault, considered premetamorphic because it does not

affect metamorphic isograds, postdates two phases of major folding. The dominant foliation in the area is axial planar to the earlier of these folding phases. In the Murphy area, however, the dominant and apparently earliest foliation is axial planar to a major structure which clearly folds isograds.

A stratigraphic model for upper Precambrian to lowest Cambrian sediments in the Blue Ridge suggests that the Chilhowee, Walden Creek, Snowbird, and Great Smoky groups are partly facies equivalent strata. This model is based on a lower Ordovician or younger age of the Murphy marble and the assumption that the floor of the basin descends monotonically southeastward. Strike of facies boundaries, in palinspastic restoration, is east-west, or as much as 30 degrees more easterly than the strike of faults of the COCORP thrust system. In its restored position, the sedimentary wedge can be tied to a wedge of autochthonous sediments beneath east-central Georgia, evident in an interpretation of COCORP seismic reflection data. There is rough correspondence between the tapered edge of the sediments and a prominent gravity gradient.

In thin-section, rocks of the Great Smoky Mountains and foothills, ranging from unmetamorphosed to the garnet zone of metamorphism, show less increase in grain size of layer silicates than expected. However, differences in character of both the main foliation in particular areas, and less obvious foliations, suggest increasing mobility of silica and other constituents and increasing dominance of lattice diffusion over grain-boundary diffusion in rocks deformed at higher temperatures.

# TABLE OF CONTENTS

| CHAPTER                                                                                               | PAGE |
|-------------------------------------------------------------------------------------------------------|------|
| INTRODUCTION . . . . .                                                                                | 1    |
| I. STRUCTURE AND EVOLUTION OF GREAT SMOKY MOUNTAINS<br>REGION, TENNESSEE AND NORTH CAROLINA . . . . . | 3    |
| Geologic Setting . . . . .                                                                            | 4    |
| Methods . . . . .                                                                                     | 6    |
| Structure of Valley and Ridge between<br>Knoxville and COCORP Thrusts . . . . .                       | 18   |
| Structure between COCORP and Hayesville Thrusts . . . . .                                             | 29   |
| Timing of Structures . . . . .                                                                        | 74   |
| Conclusions . . . . .                                                                                 | 77   |
| II. PALINSPASTIC RESTORATION OF OCOEE BASIN, BASED ON<br>COCORP GEOPHYSICAL DATA . . . . .            | 80   |
| Geologic Setting . . . . .                                                                            | 80   |
| Comparison of Blue Ridge and Valley and Ridge<br>Thrust Architecture . . . . .                        | 82   |
| Stratigraphy of Lower Cambrian (Rome) to<br>Middle Ordovician . . . . .                               | 88   |
| Footwall Interactions of COCORP Fault . . . . .                                                       | 92   |
| Interpretation and Restoration of COCORP Seismic<br>Reflection Data . . . . .                         | 94   |
| Sub-Rome Stratigraphy of the Blue Ridge . . . . .                                                     | 99   |
| Palinspastic Restoration . . . . .                                                                    | 113  |
| Conclusions . . . . .                                                                                 | 116  |
| LIST OF REFERENCES . . . . .                                                                          | 117  |
| APPENDICES . . . . .                                                                                  | 126  |
| A. TECTONIC MICROFABRIC IN GREAT SMOKY MOUNTAINS REGION . . . . .                                     | 127  |
| B. GUIDE TO SELECTED OUTCROPS IN THE BLUE RIDGE OF<br>TENNESSEE . . . . .                             | 142  |
| C. MILEAGE LOG FOR APPENDIX B . . . . .                                                               | 154  |
| D. EXPLANATION FOR PLATES . . . . .                                                                   | 160  |
| VITA . . . . .                                                                                        | 165  |

# LIST OF FIGURES

| FIGURE                                                                                                               | PAGE |
|----------------------------------------------------------------------------------------------------------------------|------|
| 1. Two Thrust Fronts in the Southern Appalachians, and Depth to Autochthonous Basement . . . . .                     | 5    |
| 2. Map Showing Location of Studies in the Literature, on Which Structure Sections Are Based . . . . .                | 8    |
| 3. Possible Relationships between Dumplin Valley and Saltville Faults . . . . .                                      | 19   |
| 4. Detail of Geologic Map of Hot Springs Window . . . . .                                                            | 34   |
| 5. Dip Arrow Map, Bedding in Miller Cove Plate at Richardson Cove . . . . .                                          | 41   |
| 6. Dip Arrow Map, Bedding in Miller Cove Plate North of Tuckaleechee and Wear Coves . . . . .                        | 44   |
| 7. Structure Along Little Tennessee River in the Vicinity of Calderwood Window . . . . .                             | 46   |
| 8. Dip Arrow Map, Dunn Creek Plate in the Gatlinburg Vicinity . . . . .                                              | 53   |
| 9. Equal-Area Projection of Axes of Fabric Elements, Dunn Creek Plate South of Tuckaleechee and Wear Coves . . . . . | 58   |
| 10. Proposed Rotational Origin of Kinks Called "Shear Cleavage" . . . . .                                            | 61   |
| 11. Northeasternmost End of Greenbrier Thrust Sheet, and Footwall, in Cross Section . . . . .                        | 64   |
| 12. Dip Arrow Map, Bedding and Foliation in Brushy Mountain Plate in Pigeon River Area . . . . .                     | 65   |
| 13. Basal Decollement in Valley and Ridge Province, in Cross Section . . . . .                                       | 83   |
| 14. Three Alternative Models of Blue Ridge Thrust Architecture . . . . .                                             | 86   |

| FIGURE                                                                                                                                   | PAGE |
|------------------------------------------------------------------------------------------------------------------------------------------|------|
| 15. Duplex Model, Applied to Footwall of Miller Cove Fault . . .                                                                         | 87   |
| 16. Line Drawing of COCORP Georgia Line 1, Modified after<br>Cook et al. (1980), and Interpretation . . . . .                            | 95   |
| 17. Interpretive Fence Diagram Showing Major Sub-Rome<br>Stratigraphic Units of the Blue Ridge,<br>Palinspastically Restored . . . . .   | 101  |
| 18. Sample Locations for Thin-Section Study . . . . .                                                                                    | 128  |
| 19. Line Drawing of Variations of Second Order Cleavage,<br>Observed in Hand Specimen, Wilhite Formation,<br>Miller Cove Plate . . . . . | 137  |

## LIST OF PLATES

### PLATE

|                                                  |           |
|--------------------------------------------------|-----------|
| I. Structure Sections 1-4 . . . . .              | In Pocket |
| II. Structure Sections 5-8 . . . . .             | In Pocket |
| III. Tectonic Map . . . . .                      | In Pocket |
| IV. Restoration of Part of Section I . . . . .   | In Pocket |
| V. Reference Divisions and Major Folds . . . . . | In Pocket |



## INTRODUCTION

The purpose of this study is to interpret the geology of a well-mapped portion of the Southern Appalachians in the light of the considerable amount of shortening which geophysical methods recently have documented. In particular, the study was conducted to evaluate the role of the late Paleozoic Alleghany orogeny in the western margin of the Blue Ridge province. This also entailed study of the early Paleozoic Caledonian or Taconic orogenic imprint in the Blue Ridge province, and Alleghany structure in the adjacent portion of the Valley and Ridge province.

Published geologic maps are the source of most of the geologic data considered in this investigation. The writer supplemented map data with study of tectonic fabric in outcrop and in thin section, in a small portion of the study area.

In keeping with Department of Geological Sciences policy that dissertations must be prepared in publishable format, the report is divided into two chapters, the text of each of which is intended to stand by itself. For this reason, there is some repetition of introductory material in the two chapters.

The first chapter presents a discussion of eight structure cross-sections (Plates I and II) and tectonic history of the study area.

The second chapter includes an interpretation of a COCORP seismic reflection profile, an outline of the stratigraphy of the study area, and a palinspastic restoration.

A study of microfabric in part of the study area did not tie in directly with the rest of the report, and is presented as the first of four appendices. The other appendices are: a brief discussion of each of several outcrops in the study area; a road log locating the outcrops; and a legend to accompany five enclosures which are presented as plates in pocket.

Reference system. To help the reader locate structures discussed in the text, a reference system has been devised. The structure sections in Plates 1 and 2 are numbered 1 through 8 from northeast to southwest, and are divided into lettered reference zones A through F, from northwest to southeast. The boundaries of the zones are marked on the sections and are located in map view on Plate 5.

As an example of the system, "S4A-5A" in the text (S for "section") refers to the region in zone A (northwesternmost zone) which appears on, and lies between, structure sections 4 and 5.

The words "guidebook stop (number)" in the text refer to an outcrop described under that number in Appendix B.

## CHAPTER I

### STRUCTURE AND EVOLUTION OF GREAT SMOKY MOUNTAINS REGION, TENNESSEE AND NORTH CAROLINA

This report investigates the structure of a 12,000 square km area straddling the Blue Ridge and Valley and Ridge provinces of the southern Appalachians. Eight cross sections (Plates I and II), constructed to the base of Paleozoic deformation, cover the terrain between Chestnut-Dumplin Valley thrusts and the Hayesville fault (Plate III). The sections are approximately limited along strike by the Tellico and French Broad Rivers. Major folds in this area are discussed in terms of interference with other major folds, kinematic relationship to thrust faults, and relation to fabric, especially foliation, visible in outcrops.

The study is largely a compilation, in the form of structure sections and text, of data in the literature. It adds to previous compilations (Rodgers, 1953, 1970; King, 1966; Hardeman et al., 1966; Hadley and Nelson, 1971; Merschat and Wiener, 1973) new conclusions, mainly based on application of techniques of balanced cross section construction. These techniques are now applicable in this area, because a new and growing data base of seismic reflection profiles (Harris, 1976; Clark et al., 1978; Tegland, 1978; Cook et al., 1979) suggest an overall structural style and the location of the base of thin-skinned deformation. Although numerous structure cross sections have been drawn in the study area, and a few have interpreted structure as deep as 3 km below sea level (King, 1966; Hadley and Nelson, 1971), prior to the

work of Harris and Milici (1977) and Roeder et al. (1978), no cross sections, extended to the base of thin-skinned deformation, had been published.

An outgrowth of Roeder et al. (1978), this report examines the structural front of the Blue Ridge in detail, and attempts to identify major structures in the Blue Ridge which may be synchronous with Valley and Ridge structures.

### Geologic Setting

The Blue Ridge and Valley and Ridge provinces of east Tennessee are part of a Paleozoic foreland fold and thrust belt on the northwest flank of the Appalachian orogenic system (fig. 1). The Blue Ridge in Tennessee is a mountainous physiographic province underlain mainly by metasandstones and metashales of Precambrian to Cambrian age. Bounding the Blue Ridge on the northwest is the Valley and Ridge province, a less rugged area underlain by Paleozoic strata, mostly carbonate rocks and shales.

In southeast Tennessee, the physiographic boundary is also a profound thrust fault, the Great Smoky fault. There is stratigraphic displacement such that the highest formation preserved in the Blue Ridge (Rome Formation of lower Cambrian age) is the same as the lowest unit exposed in the Valley and Ridge. Windows in the thrust are within the Blue Ridge, up to 15 km southeast of the Valley and Ridge. On the basis of a seismic reflection profile (Cook et al., 1979), an event which probably represents a horizon in the Rome Formation can be shown to be displaced a minimum of 140 km on the Great Smoky fault.

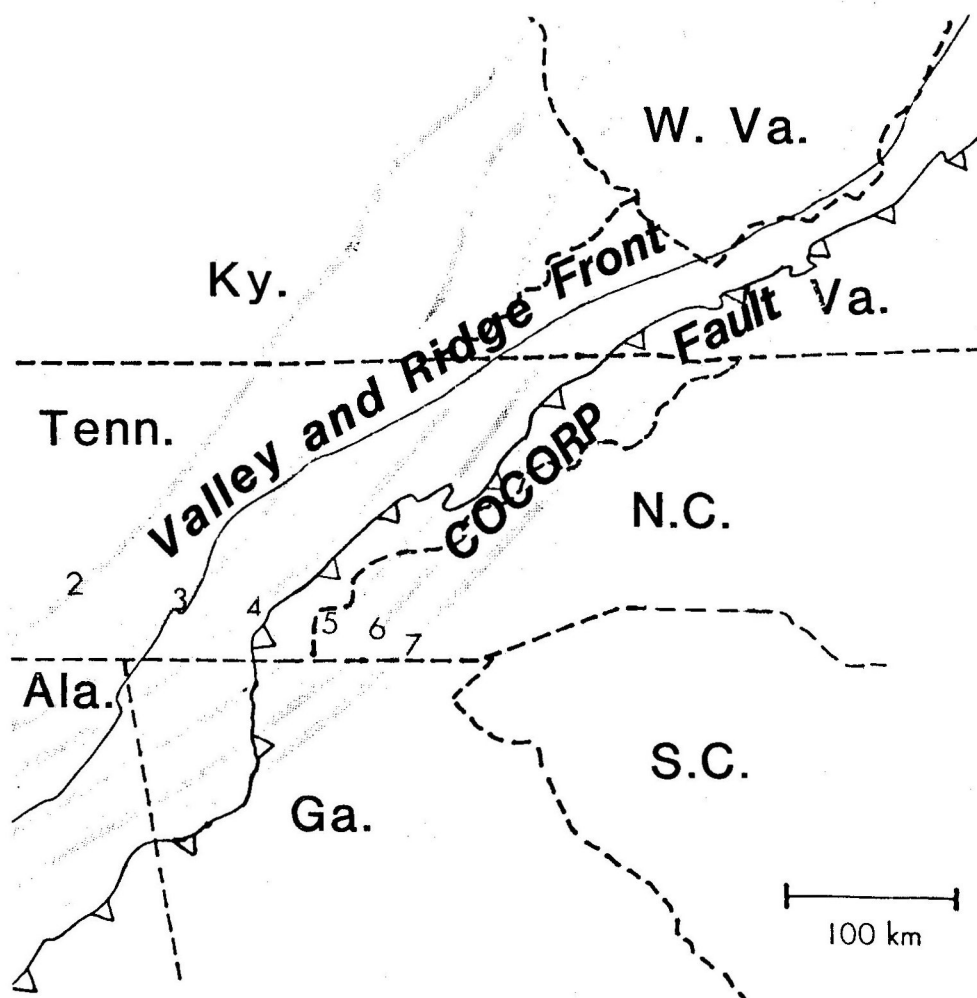


Figure 1. Two thrust fronts in the southern Appalachians, and depth to autochthonous basement.

Shaded lines: contours in km on depth to autochthonous basement, derived from seismic data cited in the text, and, west of the Valley and Ridge structural front, after King (1969).

In northeast Tennessee, the structural discontinuity crops out somewhere west of the physiographic boundary. At least one thrust (Holston Mountain fault) carries rocks spanning the two stratigraphic sections separated by the Great Smoky fault further south. A more northwesterly thrust (Pulaski fault) emerges entirely within Paleozoic rocks, but facies contrasts between rocks on either side of the fault suggest that it has very large displacement (Rodgers, 1953). A seismic reflection profile, from just northwest of the Holston Mountain fault trace to the Inner Piedmont in North Carolina, was recently made available by the U.S. Geological Survey (1980). Roeder (in prep.) interprets the profile to confirm Rodgers' (1953) suggestion that sub-Rome strata in the Mountain City window are in the Pulaski thrust sheet, and to show over 100 km of slip on the Pulaski fault. This would make the Pulaski fault, which crops out entirely within the Valley and Ridge physiographic province, the northwestern structural limit of the Blue Ridge.

The Great Smoky-Pulaski thrust is referred to in this study as the COCORP fault, because geophysical work, beginning with that of the Continental Consortium for Reflection Profiling (COCORP; Cook et al., 1979) has set it apart from the series of thrusts of smaller displacement on both sides of it.

### Methods

The interpretations shown in Plates I and II depend on the validity of surface geology, subsurface information (primarily the depth to the base of deformation) and assumptions about the tectonic style. Particular

uncertainties, and some alternative interpretations, are noted directly on the structure sections and in the text of this report. The general approach and its main limitations are outlined in the following paragraphs.

### Surface Geology

Geologic maps and fabric studies which were used in cross section construction are located in figure 2.

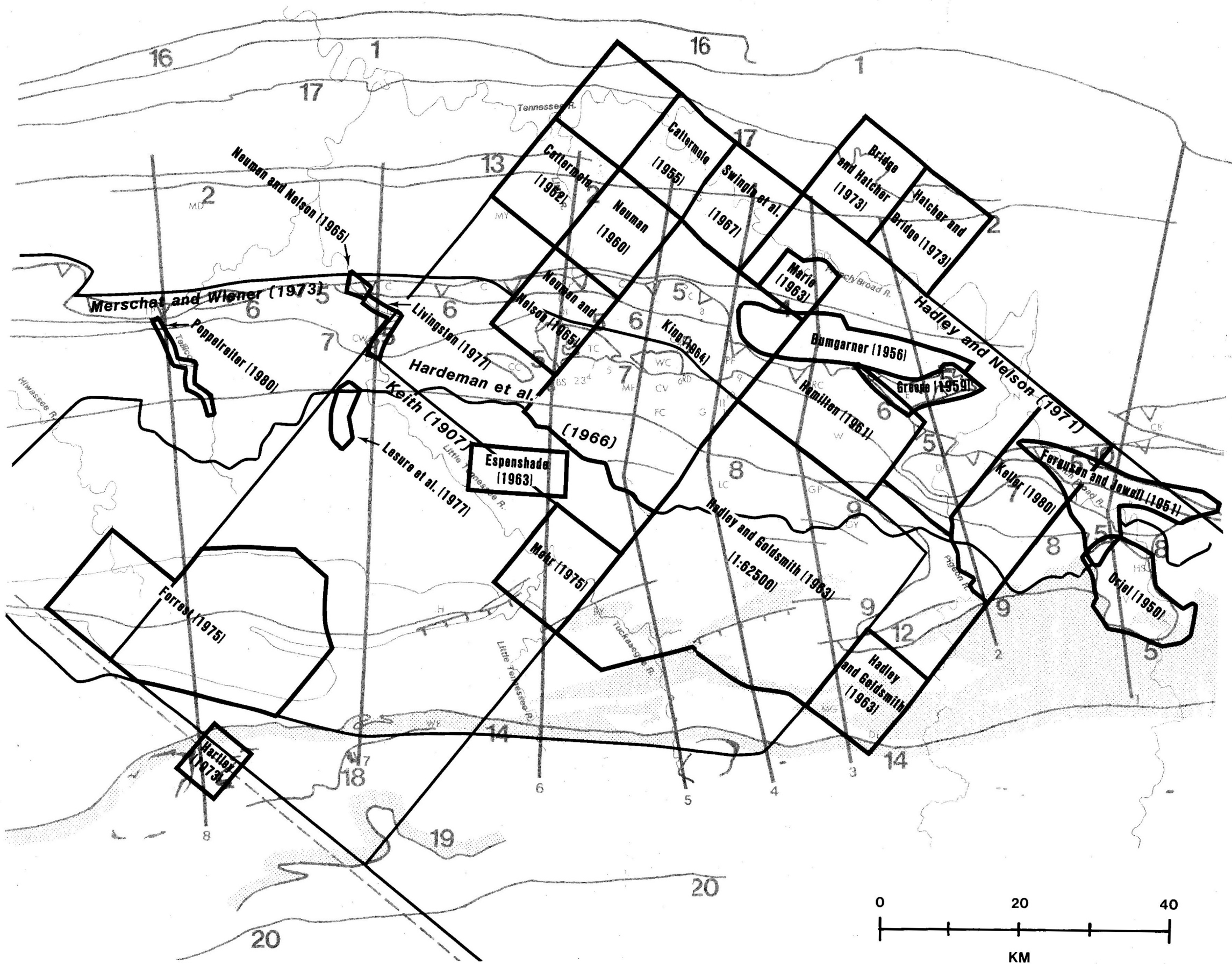
Surface geology is most useful and reliable if stratigraphy is finely subdivided, a high density of (bedding and foliation) attitudes is available, and geologic contacts have been located with precision. These conditions generally are best met where geology has been mapped at a scale of 1:62,500 or larger (areas enclosed by heavy lines in fig. 2). Geologic control is poor where no mapping is available at scales larger than 1:125,000. Geologic control is also poor, even where 1:24,000 mapping is available, where thick, monotonous stratigraphic sequences are exposed. It is difficult to estimate structural relief on major folds when contacts cannot be reliably correlated from one limb to the other. In addition, the locations of major faults, which enter the rocks from better defined strata, are often largely hypothetical.

A type of map, here called a dip-arrow map, was devised to make maximum use of strike and dip information where stratigraphic control is poor, and to study fold interference in map-view. Each dip-arrow map of a particular area shows only the attitudes of a single fabric element — for example bedding, or the dominant foliation. The attitude of an s-surface is shown as an arrow pointing in the dip direction, with the

Figure 2. Map showing location of studies in the literature, on which structure sections are based.

Thin lines enclose areas of reconnaissance maps, the references to which are in italics. Scale of such maps is 1:125,000 or 1:500,000. Thick lines enclose areas of detailed maps and fabric studies. Scale of detailed maps is 1:24,000, unless noted otherwise.





length of the arrow proportional to the degrees of dip. A dip-arrow map is intended to make it easier to sort out average orientations, boundaries between domains of different attitudes, and possible interference patterns where two major folds intersect.

The dip-arrow maps used in this study were derived from published geologic maps, using a tracing paper overlay, or a computer plotting routine. In the Blue Ridge portion of the study area, nearly all detailed mapping was examined by this method. Representative portions of dip-arrow maps are reproduced as figures.

A set of computer programs for translating attitudes from maps into stereographic projections was written to supplement the dip-arrow maps. Bedding or foliation attitudes were read into a data file using a digitizing table, sorted into subfiles by geographic area, and plotted in stereographic projection.

#### Base of Deformation

The concept of thin-skinned deformation (i.e., that basement is not involved in the structures of a foreland fold and thrust belt) was first applied in the Valley and Ridge in Tennessee (Rich, 1934), and has been advocated, at least on a limited scale, by several authors (e.g., Rodgers, 1953; King and Ferguson, 1960; King, 1964). Recently, seismic reflection data have not only confirmed this principle, but have also furnished approximate depths to the undeformed basement (Tegland, 1978). These data have shown that the base of deformation is probably at or close to the base of the lower Cambrian Rome Formation. The new data suggest that regionally, the base of deformation dips southeasterly at

about one or two degrees, to at least as far as 140 km southeast of the Blue Ridge front (Cook et al., 1979).

A strong, gently southeast-dipping seismic event is seen on seismic reflection profiles of the Valley and Ridge and Blue Ridge. In some areas, the event appears to be duplicated by thrust faulting. The location of the event, where it is not evidently dislocated by thrusting, is near the basement top as previously estimated from aeromagnetic data (Watkins, 1964) and stratigraphic thickness in the Cumberland Plateau (Roeder et al., 1978).

The event is believed by most workers to correspond to velocity contrasts in the lower part of the Rome Formation (e.g., Harris, 1976; Tegland, 1978; Fred Cook, pers. comm., 1980), because segments displaced on thrust faults project into surface exposures of that unit (Tegland, 1978).

The event is interpreted to be above, but quite near to the base of thin-skinned deformation (Harris, 1976; Roeder et al., 1978), because on the one hand it does appear to be duplicated on thrust faults. On the other hand, each fault appears asymptotically to merge into Rome in the footwall of the fault, with no room left between the fault and Rome in the hanging wall for any sub-Rome material. This is an important principle on which the cross sections depend, as it implies that in the Valley and Ridge (i.e., in the foreland of the COCORP fault) any Rome Formation elevated above the basement top must be underlain by material from an overridden tectonic unit, and not by sub-Rome material such as Shady Dolomite or Chilhowee Group.

In order to choose the base of deformation for each of the structure sections, the simplifying assumption was made that contours on the base of deformation are straight lines over the area of study. The straight line contours were fitted to depths to the Rome reflector, obtained from the studies of Harris (1976), Clark et al. (1978), Tegland (1978), and Cook et al. (1979). This required simplified depth conversions of the Harris and the Cook et al. data. The same seismic velocities as those estimated by Tegland (1978) were applied to the former study, whereas, for the Cook et al. data, stacking velocity near the reflector was taken as the average velocity.

The data suggest that the base of deformation beneath the study area strikes about 40 degrees east of north, or about 15 degrees more northerly than regional structure at the surface in the study area (fig. 1, p. 5). The contours may be projected into contours on depth to basement beneath the little deformed Appalachian foreland in Virginia and West Virginia (King, 1969).

It is stressed that the contours in figure 1 represent a rough approximation. Deviations of more than one to two km from true depths could affect the accuracy of the structure sections. The approximation is believed to lie within such limits of error, because it generally agrees with values of Roeder et al. (1978), arrived at by different methods. The Roeder et al. estimate was based on aeromagnetic data and stratigraphic thickness at the Cumberland Plateau, along with adjustments of the base of individual sections as the sections were drawn. The estimate of Roeder et al. is generally less than 1 km different from the present seismically based estimate.

## Tectonic Assumptions Used in This Study

A cross section represents structures which have developed through reasonable stages from a reasonable undeformed geometry, with negligible change in rock volume. Cross sections constrained by this principle are called balanced (Dahlstrom, 1969). It turns out that many sections in the literature cannot be restored to the undeformed state, or restorations of the sections show unreasonable fault trajectories or stratigraphy.

Ideally, each balanced cross section is accompanied by a restored version, constructed at the same time (Elliott and Johnson, 1980). The end sections (S1 and S8) of this study were so constructed, whereas the remaining sections depend on application of several rules, which improve the chances that a cross section will pass the restoration test.

Principles of balanced sections in foreland belts. Although no set of rules is applicable to all tectonic settings, one can exploit the fact that a restricted number of structural forms exist in a given structural environment (Dahlstrom, 1969). A foreland fold and thrust belt such as the Appalachian Valley and Ridge or the Alberta Rockies and Foothills contains a family of structures: concentric folds; thrusts, often folded, which sole into a master detachment; and tear faults and related transverse features. An additional element in the Cordillera which has not been widely observed in the Appalachians is late listric normal faults.

Rules applied with success in hydrocarbon exploration of the Canadian Rockies (Bally et al., 1966; Dahlstrom, 1970) can be used,



with reservations discussed below, in the area of study. The rules include the following:

1. All stratigraphic horizons are shortened equally (assumes plane strain and concentric folding).
2. Thrust faults cut up-section in the direction of thrusting (based on initial concave-up trajectory and an undeformed foreland).
3. Thrust faults put older beds on younger (since they are contractional faults).
4. Map-view information may be projected down the plunge of a cylindrical structure.
5. Total shortening in adjacent cross-sections is nearly the same.
6. The base of deformation is a planar or gently curvilinear surface (observation of velocity-corrected seismic, mainly in Canada).
7. Thrusts sole into larger thrusts, including the base of deformation, at angles less than 30 degrees (seismic observation).
8. Thrust typically climb section rapidly through competent horizons, and travel considerable distances in incompetent horizons (based on fault preference vs. stratigraphic level plots).
9. A thrust fault which dips toward the foreland was folded after movement (initial thrust trajectories are concave-up).
10. Sheet dip of strata toward the foreland implies a folded thrust beneath, a thrust climbing section relative to its upper block, or both.

11. Unless hard stratigraphic data to the contrary is available, thickness of a formational unit within a thrust-panel in a given cross-section is taken to be constant.

12. A folded thrust reflects a duplex fault setup (a thrust has a lower, later branch which incorporates part of the lower block into the upper) within the fault itself, or a more external thrust.

With few deviations from these rules, consistent sections in agreement with seismic data may be constructed in the northwestern Valley and Ridge, external to the study area (Roeder et al., 1978). However, several of the principles encounter limitations in the eastern Valley and Ridge (Roeder et al., 1978; Roeder et al., 1980) and only weakly constrain sections in much of the Blue Ridge.

Limitations in preceding principles. Folding is apt to be nearly concentric in largely competent sections of strata, but may not be concentric in thick sections of dominantly fine-grained rocks, or any body of rocks deformed at elevated (upper greenschist facies or higher) temperatures. The two earlier phases of folding observed in the Ravensford anticline (S3D-3E) are examples of nonconcentric folding.

A thrust which overrides previously folded beds may violate rules 2, 3, and 8. Any branches of the COCORP fault system which affect Taconic (early Paleozoic) structural elements are expected to be fold-discordant. There is also evidence that the COCORP family of thrusts overrides some older Valley and Ridge belt structures (Roeder et al., 1980, and discussion below).

Over long distances, most structures are noncylindrical, but rule 4 can generally be applied by selecting short, cylindrical segments. Dip-arrow maps and stereonet plots were used to determine cylindrical segments, particularly where fold interference complicates the pattern.

The smoothness of the base of deformation is well-established in the Canadian Cordillera, where subsurface data is abundant (Bally et al., 1966; Price and Mountjoy, 1970), but has not been proven in the southern Appalachians. Abrupt steepening of the basement top is apparent in locations on the depth sections of Tegland (1978), but errors in velocity corrections probably cannot be ruled out.

In the Canadian Rockies, plots of fault preference versus stratigraphic level (Dahlstrom, 1970) have demonstrated a correlation between thrusts and particular incompetent zones. In spite of the fact that this correlation was first suggested in Tennessee (Rich, 1934), no systematic study of fault preference in the southern Appalachians is known to the writer. The lower Cambrian Rome Formation, various middle Ordovician units, and the Chattanooga Shale of Devonian-Mississippian age are considered favorable horizons, particularly in the western Valley and Ridge (Harris and Milici, 1978). In the eastern Valley and Ridge, the state geologic map (Hardeman et al., 1966) suggests that other horizons, such as the middle Cambrian Conasauga Group and the Cambrian to Ordovician Knox Group, are favored as well. The Great Smoky fault overrides Middle Ordovician clastics (Tellico and Sevier formations) from the French Broad to the Little Tennessee Rivers, at windows as well as along its main trace.



The presumption of constant thickness of units applies most realistically to shelf sequences, and is mainly a convenient assumption in basinal sequences. Pinchouts of units of the Snowbird Group (S3E-4E) are an example of breakdown of this rule in the Blue Ridge.

In a duplex structure, a thrust bifurcates and reunites around a fault slice (Dahlstrom, 1970). The lower branch, or floor thrust rejoins, and does not cross-cut, the upper, older surface of movement. Roeder et al. (1978) suggest that in the eastern Valley and Ridge, another type, the polyphase folded fault structure, is also present. In such a structure, the lower fault is inferred to rise from the master decollement, rather than branch from a lesser thrust, and steepen upward, often crosscutting the higher faults. A polyphase interpretation is suggested when a thrust is thought to be tightly folded. Although the Dumplin Valley and Chestuee faults are shown in this study and in Roeder et al. (1978) as polyphase structures affecting the Saltville fault, it is not proven that the Saltville is affected, and alternative interpretations can be constructed.

In summary, the cross sections depend on a number of geometric rules which can be applied, with discretion, to a foreland fold and thrust belt. The remainder of this chapter describes the application and limitations of these rules, with respect to particular structures.

## Structure of Valley and Ridge between Knoxville and COCORP Thrusts

### Overview

The Valley and Ridge province is 50 to 88 km wide in Tennessee. It is bounded on the northwest (external side) by the Cumberland Plateau. The boundary is a structural front, northwest of which thrusting is almost entirely confined to bedding planes. A pair of closely related thrusts, the Beaver Valley and Saltville faults, strike along the middle of the belt from Georgia to Virginia.

Strike length (total 675 km) and a prominent middle Ordovician facies contrast (Walker, 1977) mark the Beaver Valley-Saltville as having major displacement in Tennessee. Based on balanced cross sections, a slip of 30-40 km is assigned to the thrust (Roeder and Witherspoon, 1978). This is by far the largest slip on any thrust external to the COCORP fault in Tennessee. The Knoxville, Chestuee-Dumplin Valley, and Guess Creek thrust faults occur between the Beaver Valley-Saltville faults and the Blue Ridge thrust complex. The Knoxville fault has been interpreted to branch at depth from the Beaver Valley-Saltville fault (Roeder et al., 1978). The Chestuee-Dumplin Valley fault family may reslice the Saltville fault at depth (Roeder et al., 1978) or branch from it (fig. 3). The Guess Creek fault is the only well-mapped member of a possible family of thrusts within middle Ordovician clastics just west of the Blue Ridge complex. Other possible thrusts in this family are mainly bed-parallel features, postulated on the basis of balanced section constructions (Roeder et al., 1978, and this study).

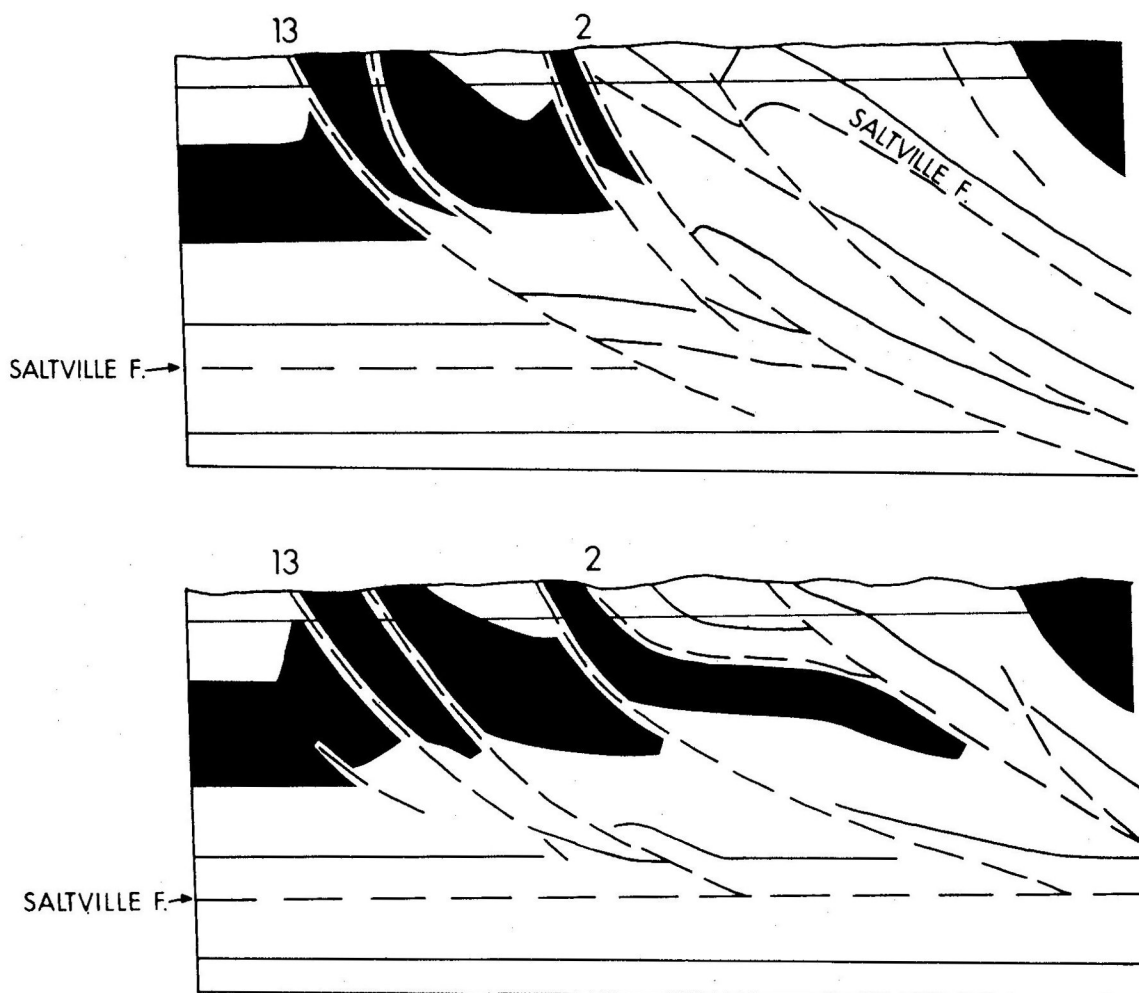


Figure 3. Possible relationships between Dumplin Valley and Saltville faults.

Black, in this figure and cross-sections (Plates I and II) is the Cambro-Ordovician Knox Group. Dashed lines represent faults. For full listing of numbers which correspond to names of faults, in this and following illustrations, see the legend for Plate I in Appendix A. Upper illustration (2a): detail from section 5. Dumplin Valley fault crosscuts Saltville. Interpretation after Roeder et al., 1978. Lower illustration (2b): alternate interpretation of same line of section, showing Dumplin Valley as a branch of Saltville fault. Segment shown is approximately 10 km long.

### Saltville Fault Passes Under Athens Syncline

The Athens syncline lies in the internal edge of the Knoxville plate (S4A-8A). The syncline extends at least 150 km from southeast of Cleveland, Tennessee to the area of Douglas Dam. Between 2.0 and 3.3 km of strata are present in the syncline above the major decollement in the Rome Formation, whereas the base of deformation is estimated to be 4.3 to 4.7 km deep. Therefore, Roeder et al. (1978) inferred an overridden plate, 1.1 to 2.7 km thick (S1A-8A), beneath the internal edge of the Knoxville plate.

The overridden plate probably surfaces in the foreland of the Beaver Valley-Saltville thrust (Roeder et al., 1978), 23 km to the northwest. This interpretation is consistent with seismic data (Tegland, 1978), the strike length of the Beaver Valley-Saltville, and with facies changes (Walker, 1977).

### Dumplin Valley Fault Family

Up to 1.9 km of structural relief due to folding is present between the core of the Athens syncline and its internal (southeast) limb. The relief is added to by several faults which appear in the core and southeast limb of the structure. The Chestuee fault (3; S6A-8A) extending from north of Maryville to east of Cleveland, and the Dumplin Valley fault (2; S1A-8A), two to three km southeast of it, are the most important of these faults. The Dumplin Valley fault overrides the internal limb of the Athens syncline and brings up strata as low as the lower Cambrian Rome Formation. Maximum structural relief between the

hanging wall of the Dumplin Valley fault and the core of the Athens syncline is 3.1 km, southeast of Knoxville.

Roeder et al. (1978) interpreted the Chestuee-Dumplin Valley fault family as a system of late thrusts, which locally involve the overridden Beaver Valley-Saltville footwall. An uninvolved footwall plate is also geometrically acceptable (fig. 3). In the latter case, the Dumplin Valley and Chestuee thrusts themselves would be major splays from the Beaver Valley-Saltville decollement, like the Knoxville thrust as shown by Roeder et al. (1978). Lesser thrusts in the Dumplin-Chestuee family would represent splays from the Dumplin Valley and Chestuee faults, both in the footwall and in the hanging wall of the two thrusts. The difference in structural style between the Knoxville fault and the Chestuee and Dumplin Valley faults would be the profusion of minor splays associated with the latter faults.

Shortening across the Chestuee-Dumplin Valley faults is about 8 km in the Roeder et al. (1978) version, and 11.5 km in the alternative version.

#### Transverse Ramp at Depth, Pigeon Forge Area

The width of the exposed Guess Creek plate is 0 to 2 km along the northwest edge of Chilhowee Mountain, but it increases abruptly to 8 km at Pigeon Forge, where the Great Smoky fault trace makes an abrupt southeasterly dogleg. This dogleg is here interpreted to reflect an offset or transverse step in a ramp in the subsurface.

Roeder et al., 1978 (section 6) and the present study (S5B) suggest that the Saltville-Beaver Valley thrust ramps from the master decollement

of the Valley and Ridge beneath, and immediately northwest of Chilhowee Mountain. Moderate sheet dips in the internal edge of the exposed Dumplin Valley plate (Neuman, 1955; Neumann and Wilson, 1960) are believed to reflect the dip of the Beaver Valley-Saltville fault beneath. To avoid discordance to the upper block, the fault surface should descend from a level of about 1.1 to 2.7 km above the base of deformation, at the external edge of the Dumplin Valley plate, to join the base of deformation 1 km southeast of the Great Smoky fault trace along Chilhowee Mountain.

Roeder et al. (1978) simply projected the postulated ramp along strike into other sections to the northeast (e.g., section 5 of that study). However, data not used in their study (Marie, 1963), suggest that the ramp is offset to the southeast, as proposed in S3B-5B. The key to this interpretation is the sheet dip of only about 12 degrees in Marie's cross sections of the Millican Creek area, opposed to 30 to 40 degree sheet dip along strike, northwest of Chilhowee Mountain.

In S3B, located about 9 km northeast of Pigeon Forge, the Beaver Valley-Saltville fault diverges from the base of deformation 1.5 km southeast of the trace of the Great Smoky fault. Moderate dips at the surface, analogous to dip northwest of Chilhowee Mountain, are expressed in the southeast limb of the Fair Garden anticline.

The possible close relation of the Great Smoky fault trace to the ramp suggests that the Great Smoky fault was emplaced with a relatively low dip, and was rotated to the present steeper dip as the Beaver Valley-Saltville fault developed. This, and the duplex structure at Newport



(S2C) discussed below, is the strongest evidence known to the writer that some Valley and Ridge faulting postdates emplacement of the COCORP fault. Other evidence, that the COCORP cuts across some earlier Valley and Ridge structures, is presented in a later section.

Although King (1964) regarded the dogleg in the Great Smoky fault as due to a supposed vertical component of offset on the steep, northwesterly striking Pigeon Forge fault mapped to the southeast, his structure contour map on the Great Smoky fault suggests a large flexure in the fault as well. The writer contends that the Pigeon Forge fault need not affect the Great Smoky fault, and that a simple flexure, reflecting the postulated transverse ramp at depth, is sufficient to explain the offset.

Directly across strike from the proposed transverse step, 40 km to the northwest, is the abrupt termination of the Beaver Valley fault against a transverse feature (Plate 3). Possibly the two transverse features are related, since they appear to affect opposite ends of the same thrust fault and are aligned with one another, but the topology of the relationship is uncertain.

Unmapped Fault, and Fold-Discordance of  
COCORP Fault, Inferred from  
Notchy Knobs Syncline

The internal edge of the Dumplin Valley plate, in the southwestern portion of the study area, is dominated by the Notchy Knobs syncline (S7B-8B). The northwest limb of the syncline is continuous with the southeast-dipping homocline at the base of Chilhowee Mountain, previously



mentioned in connection with the ramp in the Beaver Valley-Saltville thrust that it suggests. The southeast limb of the syncline gradually emerges from beneath the Great Smoky fault as one goes southwestward along strike. The stratigraphically lowest unit exposed is the middle Cambrian Conaseaga Group, which crops out at Tellico Plains.

The structural high at Tellico Plains is difficult to explain with simple tectonic assumptions which are adequate to account for structures along strike to the northeast. The problem is twofold: what fills the space below the outcropping Conasauga rocks and above the base of deformation? and how is the supposed presence of rocks in the Knox Group beneath the Blue Ridge (Hatcher, 1971) to be reconciled with overriding by the Great Smoky fault of a lower stratigraphic unit?

The explanation suggested here (S8B) is that the high is cored by material carried on an unmapped thrust (3), which has more than 20 km of slip; and that the Great Smoky fault discordantly cuts the structure. Admittedly, this is not a simple solution, but two other possibilities appear less likely, as explained below.

The first alternative, similar to an interpretation of the anticline at Wear Cove in the regional cross section by Harris and Milici (1978), would be to core the structure with sub-Rome material such as Shady Dolomite, Chilhowee Group, and Ocoee Supergroup. Although upper Chilhowee through Rome material is carried above Bullet Mountain fault, a fault cropping out 1 to 3 km northwest of the Great Smoky fault, the Bullet Mountain is probably a footwall imbrication of the Great Smoky (Rodgers, 1953). The COCORP data show a fairly continuous probable Rome

event beneath this area, with no suggestion that sub-Rome material is involved in the footwall of the Bullet Mountain fault.

Another alternative, shown in section 8 of Roeder et al. (1978), is that Rome, Conasauga, and some Knox material pass beneath the Rome through Tellico section of the core of the syncline, and are involved in a duplex structure beneath Tellico Plains. The COCORP data indicate the base of deformation may be shallower, and stratigraphic thicknesses of Neuman (1955) suggest the syncline is deeper, than the Roeder et al. section shows. Their section also indicates that the proposed fault passing between the Notchy Knobs syncline and the base of deformation is the Saltville fault; the fault merges with the Great Smoky fault near the southeast end of their section. This interpretation does not agree with their sections along strike, and Roeder (pers. comm., 1980), now regards it as untenable.

The solution here proposed presents the high at Tellico Plains as a duplex folded-fault structure, cored with Rome through Knox material rather than sub-Rome rocks. However, a duplex must have a roof thrust and a floor thrust, and the two have to merge external to the duplex, and emerge somewhere at the surface. An unmapped fault is required. Since a position close to the base of the middle Ordovician clastics seems to be a favorable gliding horizon at several other locations, and exposure of these strata is poor enough that a fault zone could be missed, the position shown in S8B is chosen for emergence of the hypothetical fault (3). The large (about 20 km) displacement of the proposed fault at Tellico Plains requires that the fault be projected

a considerable distance along strike. It is therefore represented at about the same position in the remaining sections (S1B-7B).

As for the relationship of the Great Smoky fault to the proposed duplex structure, the alternative presented by Roeder et al. (1978) shows the sub-Saltville fault material, supposed to be involved in the duplex, including rocks of the Knox Group, extending beneath the Blue Ridge. Again, this requires the Saltville fault to be a branch from the Great Smoky fault. The writer also lets material involved in the duplex extend beneath the Blue Ridge, but to avoid having the postulated unmapped fault be a branch of the Great Smoky (hence the leading edge of the COCORP system), the Great Smoky fault has to override the duplex discordantly. The structures shown in S8B, particularly the discordantly-cut higher unit preserved beneath the Great Smoky fault, are at least consistent with the COCORP data, which show southeasterly-dipping reflectors in that area.

Joining this conclusion to the relation between the Great Smoky fault and proposed transverse step in the Saltville at Pigeon Forge (S3B-5B), the argument is made that the COCORP fault continued to move after some of the most easterly thrusts of the Valley and Ridge were emplaced, but ceased movement before the Saltville fault was created. The first part of the argument is consistent with the Roeder et al. (1980) hypothesis of major fold-discordant thrusting in the eastern Valley and Ridge, whereas the second part agrees with the overall internal to external development of a thrust belt advocated by many authors (Price and Mountjoy, 1970; Elliott, 1976; Roeder et al., 1978) but disputed by others (Harris and Milici, 1978).

Other Evidence for Time Overlap of COCORP  
and Valley and Ridge Thrusting

The Fair Garden anticline (S2C-3B) lies within the Guess Creek thrust plate, extending northeast from Pigeon Forge parallel to the strike of the Great Smoky thrust. The distortion of the fold in map view near S2C suggests that the subsurface features affecting the geometry of the northwest limb of the Fair Garden are partly independent of those affecting the southeast limb. As has been noted, the southeast limb of the Fair Garden anticline may be interpreted as the offset continuation of the homocline northwest of Chilhowee Mountain (due to a proposed ramp in the Saltville fault at depth). Bedding strikes parallel to the trace of the Great Smoky fault, and both bend to a more northerly trend northwest of English Mountain. The northwest limb is accounted for according to a standard principle of thin-skinned tectonics: dips toward the external part of the orogen indicate that a gently dipping buried thrust is climbing section relative to the hanging wall. The Guess Creek fault, mapped as far northeast as the line of section 3 (Marie, 1963), and projected into section 2, is suggested to be that buried thrust, and change in decollement level between two likely sliding horizons, the Rome Formation and the lower part of the Ordovician clastics, is hypothesized.

At the northeast end of the Fair Garden anticline (near S2C), the Middle Creek thrust, parallel to bedding on the southeast limb and to strike of the Great Smoky fault, cuts across the northwest limb of the anticline. This suggests that the northwest limb, if it is different

in origin from the southeast limb as is here advocated, is the older of the structures, and may predate final emplacement of the Great Smoky fault. Because of this rather indirect argument, the writer suggests that the Guess Creek fault, like the unmapped thrust suggested at Tellico Plains, was initiated before final stages of COCORP faulting.

The Great Smoky fault trace has a major reentrant on the southeast side of English Mountain, near Newport (S2C). The reentrant is apparently due to a large, southwest-plunging anticline, here called the Newport anticline, which affects the Great Smoky fault. Because the base of the Rome Formation, projected at depth on the basis of stratigraphic thickness below the Knox Group rocks at the surface, is considerably higher than the base of deformation, the Newport anticline is interpreted as a duplex folded-fault structure (S2C). In the interpretation, roof and floor thrust merge under English Mountain, and emerge among middle Ordovician clastics to the northwest, either as the Guess Creek fault or as an unmapped bedding-plane thrust. S2B-2C suggests the postulated thrust to be the same as the hypothetical fault (3) projected from the southwest (S8A).

In spite of the clear post-Great Smoky fault age of the major Newport structure, at several locations, folds in rocks of the Guess Creek plate appear to be cut discordantly by higher thrust faults. Instances in which the Pulaski fault may discordantly override folds in the Guess Creek plate are discussed below, together with discussion of the Pulaski plate.



## Structure between COCORP and Hayesville Thrusts

### Overview

Several possible branches from the COCORP fault crop out southeast of the main trace of the Great Smoky thrust. These include the Miller Cove (6), Dunn Creek (7), and Brushy Mountain (8) faults. The Brushy Mountain fault has been mapped only in the northeastern part of the study area (S1D-2D), but it may connect or correlate with the Gatlinburg, Nichols Cove, and Sassafras Ridge faults.

Metamorphic isograds, as mapped by Hadley and Goldsmith (1963) show that motion on the Greenbrier fault (9) had ceased by the time isograds were set, during the early Paleozoic.

Thrusts of uncertain age, cropping out within the Greenbrier thrust place (S7C-8C), are postulated to account for occurrence of basement in anticlines in the southeast, contrasted with absence of basement in anticlines in the northwest part of the Greenbrier plate.

The Mary King Mountain-Braden Mountain "slide" (Forrest, 1975) is a major thrust in the core of the Murphy syncline, which extends from southwest of Bryson City, North Carolina, to well past the North Carolina-Georgia state line (Merschhat and Wiener, 1973).

Southeast of the area of this study is a belt of strongly metamorphosed sediments with abundant mafic and ultramafic inclusions. Hatcher and Butler (1979) mapped the northwest edge of the belt in the Wayah Bald area as an isoclinally folded, premetamorphic thrust (Hayesville fault).

The thrust complex markedly changes, especially in stratigraphic level of units within thrust sheets, between Pigeon and French Broad Rivers southeast of Newport (Keller, 1980). In addition, the Pulaski thrust plate, which brings Cambrian to Ordovician strata of an eastern facies over more typical Valley and Ridge lower Paleozoics, appears in the Newport area as a major footwall imbrication beneath the Great Smoky thrust. The Pulaski plate is discussed along with the Blue Ridge complex, although physiographically it belongs to the Valley and Ridge.

#### Pulaski Plate

The Pulaski fault (10) appears only in cross section 1 (SLC). Considerable facies changes occur in the Knox and Conasauga Groups across the Pulaski fault, suggesting that it has major displacement (Rodgers, 1953).

Major folds, both within and beneath the Pulaski plate, seem to be discordantly cut by the Pulaski and associated thrusts. A discordant relationship between the Pulaski fault and folds in its footwall and hanging wall was mapped at the Babbs Knobs "flap" by Byerly (1966), northeast of the area of this study. Reconnaissance maps (Rodgers, 1953; Hardeman et al., 1966) suggest continuation of the discordant relationship southwest of Babbs Knobs, particularly in the Caney Branch area, traversed by section 1 of this study. Folds, suggested by the trace of the Knox-middle Ordovician contact (Plate 3), are cut off by a low-dipping Pulaski thrust surface. The interpretation in section 1, after Roeder et al. (1980), shows two thin thrust plates in the Caney



Branch area, both discordant to folds in both footwall and hanging wall. The assembly has been disrupted by later high-angle reverse faults.

In the reentrant of the Great Smoky fault at Newport, there is considerable structural relief on steep-limbed, tight folds, which should result in a much more irregular Great Smoky fault trace, if the folds postdated thrusting. A discordant relationship is shown in S2C. In addition, slivers of Knox Group rocks and Blockhouse Shale beneath the Great Smoky fault have been interpreted as thin plates bounded by fold-discordant thrusts. The interpretation is suggested by detailed mapping (Hamilton, 1961) at the extreme southwest end of the reentrant at Newport.

Although the oldest rocks exposed above the trace of the Pulaski fault in Tennessee belong to the Conasauga Group, of middle Cambrian age, rocks as low as the ?Precambrian to Cambrian Chilhowee Group may be borne on the thrust in the subsurface. Rodgers (1953) suggested that Chilhowee rocks, cropping out in the Mountain City window of northeast Tennessee, are in the Pulaski plate, and this suggestion is supported by a recent seismic reflection profile (U.S. Geological Survey, 1980). In the area of the present study, rocks of the Hot Springs window may occupy a similar tectonic position (Roeder et al., 1978; Keller, 1980). The writer considered a different interpretation, because of the possible facies contrast between Conasauga rocks in the window and above the Pulaski trace (Oriel, 1950; Rodgers, 1953). In the alternate interpretation, the content of the Hot Springs window is a slice enclosed between branches of the Great Smoky fault, and transported

relative to the Pulaski plate. The writer was unable to balance such a construction, and returned to the view that the window content is part of the Pulaski plate.

The principal fault framing the window (Mine Ridge fault) is probably equivalent to the Great Smoky fault (Rodgers, 1953). The warp of the fault and strata exposed in the window, according to the thin-skinned assumptions, implies a duplex structure, probably in the buried Pulaski fault (Roeder et al., 1978; Keller, 1980). The stratigraphic level of the duplex-enclosed slice is open to speculation. Roeder et al. (1978) proposed that rocks as young as Cambrian to Ordovician Knox Group may occupy the slice, but the writer favors involving no rocks younger than the lower portion of the Conasauga Group. This is based on the probability that the Pulaski, beneath and to the northwest of the Hot Springs window, climbs section from the Precambrian to the lower Conasauga, and speculation that the inferred slice is simply a fragment plucked from the footwall of the initial ramp fracture. The process, illustrated in Plate IV, is discussed below, following presentation of some details of the structure.

The anticline which cores the Hot Springs window is one of the largest folds in the area of this study. A structural relief of 4.5 km is present within the window alone, between basement close to the southeastern edge and middle Cambrian Honaker Formation at the northwest edge. The anticline is actually contributed to by two fold sets of different orientations. One is a single anticline with a steep north limb, which trends east-west. In the north half of the window, strata

dip steeply northward, whereas they have gentle or southeastward dips in the south half of the window. The other macroscopically obvious fold set trends about N40E. Refolding of the Great Smoky fault is evident on the southwest side of the window. A syncline of this fold set has a structural culmination at Vann Cliff (fig. 4), exactly where its axial trace crosses the axial trace of the major E-W-trending anticline. In a domed structure, basement comes to the surface where an anticline of the N40E set coincides with the axial trace of the E-W anticline.

The interpretation to depth (S1E) depicts the Great Smoky fault as folded by a duplex structure, within the buried Pulaski fault. Palinspastic restoration (Plate IV) illustrates the development of the structure.

Part A of Plate IV shows the position of fractures which were to develop into the Pulaski fault, Great Smoky fault, and associated higher thrusts. The fracture that became the Great Smoky fault ramped from a horizon in the Precambrian (near the base of the Sandsuck Formation) to a position in the middle Cambrian Conasauga Group, and finally ramped upwards through the Cambrian to Ordovician Knox Group.

The Pulaski fault branched downward from the Great Smoky fault somewhere southeast of the area shown, and propagated within the basement, not far below the base of the sediments. About 11 km northwest of the site of the ramp in the Great Smoky fault, it ramped upward to the Rome Formation. The distance between the two ramps is constrained rather closely if S1E is correctly drawn, because no rocks lower than the Conasauga Group appear in the Pulaski thrust sheet in

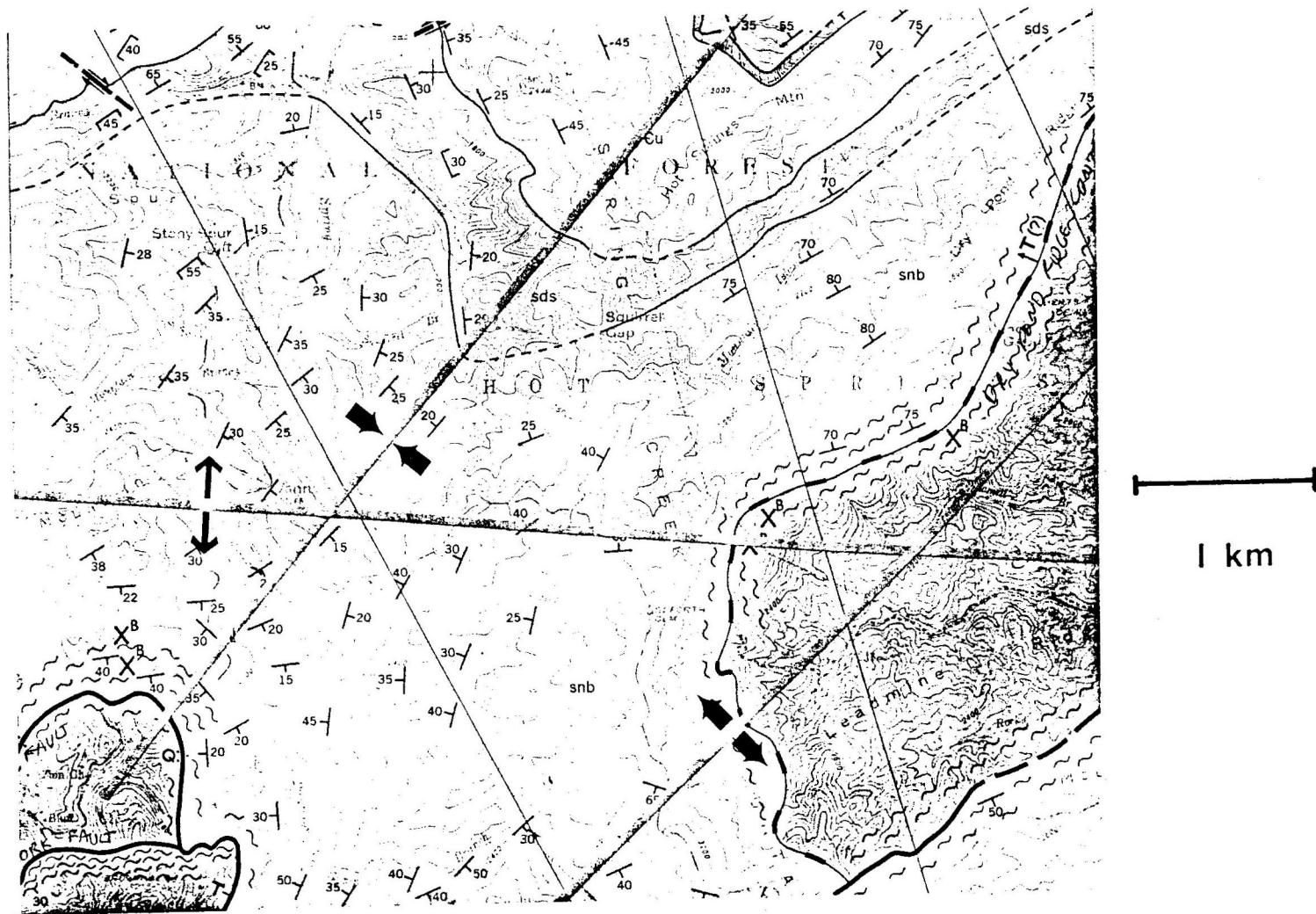


Figure 4. Detail of geologic map of Hot Springs window (after Oriel, 1950).

the foreland of the Great Smoky fault's main trace, only 13 km northwest of the Hot Springs window.

The Pulaski ramp may have had an east-west strike, accounting for the strike of the earlier of the two major fold sets in the window.

Still another fault, the floor thrust of the duplex structure affecting the earlier thrusts, propagated at the Sandsuck decollement level, and ramped up to rejoin the old Pulaski fault about 23 km northwest of where it split away from that fault. The ramp in the floor thrust may have had a northeasterly strike, accounting for the orientation of the second major fold set in the Hot Springs window.

Before movement ceased on the floor thrust (Part B of Plate IV), a new fracture propagated in its footwall near the base of the Rome formation. This fracture was to become the master decollement into which root the thrust faults of the present Valley and Ridge. The proposed fold-discordant relation between the Pulaski fault and some Valley and Ridge structures (Roeder et al., 1980, and this study) requires time overlap of movement on this fracture and on the floor thrust of the Hot Springs structure. In the final stage of development of the Hot Springs structure (Part C of Plate IV), the Pulaski fault — floor thrust chopped off the crests of anticlines generated by movement on the Valley and Ridge master decollement.

Two potential problems appear in the restoration, both of which could have stratigraphic explanations. First, the upper portion of the Chilhowee Group (CU) is much thicker in the window than in the area palinspastically to the southeast. Second, if the up-plunge projection



of structure in Part C of Plate 4 is correct, there is apparent misfit in the restoration on the southeast side of the window, in which the Sandsuck Formation (wss) is missing.

The basement exposed in the window, believed to be in the Pulaski thrust plate, may be in the most external tectonic position of any allochthonous basement south of Virginia, including that at Fort Mountain, Georgia, and the Holston Mountain thrust plate of northeast Tennessee. What is peculiar about this basement is that it is overridden by thrusts, the most external of which reach no deeper in the section than the base of the Chilhowee Group. If thrust faults developed from internal to external, or from highest to lowest in the final assembly of plates, then development of the Pulaski fault at the Hot Springs window represented renewed deepening of the base of deformation as faulting progressed.

#### Intra-Great Smoky Fault Zone

Cove windows. Ordovician rocks of the Knox Group and the Blockhouse Shale appear in five windows, 7 to 15 km southeast of the main trace of the Great Smoky fault, between Pigeon Forge and the Little Tennessee River (S5C-6C, 6B-7B). There are marked facies changes in the Knox Group, between the windows and nearby Valley and Ridge exposures, so that carbonate rocks in the windows, like those of the Pulaski plate, are assigned to the Jonesboro or eastern facies of the Knox Group (Rodgers, 1953; King, 1964; Neuman and Nelson, 1965), whereas nearby Knox strata cropping out in the Fair Garden anticline (3B) are assigned

to more westerly facies (Bumgarner, 1956). For this reason the writer departs from structure sections by King (1964) and Neuman and Nelson (1965), and agrees with section 6 of Roeder et al. (1978), that rocks of the windows are large slices, carried within the Great Smoky fault zone to their present position, rather than part of the Guess Creek plate.

In Tuckaleechee Cove window (S6B-6C), the only window in which exposure is good, fault slices and folds, some discordantly cut by thrusting, complicate the structure (King, 1964, Plate 4; Neuman and Nelson, Plate 2). Immediately below the Great Smoky fault for more than 75% of its trace around the window, a 50 to 100 m thick slice of Jonesboro Limestone is thrust over Blockhouse Shale. In parts of the window, particularly the northwest corner, strata beneath the Jonesboro slice are in unfaulted stratigraphic sequence, dipping gently beneath the Great Smoky fault, which has approximately the same attitude as the beds. Elsewhere, at Little Mountain, bedding is about parallel to the fault above it, but the top of Jonesboro — base of Blockhouse sequence is repeated three times in a stack of fault slices. Lastly, at the northeast end of Tuckaleechee Cove window, bedding is not generally parallel to the Great Smoky thrust, but dips uniformly southeasterly at 20 to 50 degrees across the whole width of the window. Hence the Great Smoky thrust, which dips gently northwestward on the northwest side of the window, cuts down-section in this stack of beds. This indicates that movement on the Great Smoky fault postdates, and is discordant to, some folds in Tuckaleechee Cove window, just as the Pulaski and Great



Smoky faults are believed to be discordant to structures in the Guess Creek plate.

Denton structure. The tectonic unit at Denton (S2C-2D), interpreted as a fault slice within the Great Smoky fault zone, differs from the cove windows in that the roof thrust climbs section in the fault slice, and the stratigraphic level is lower.

The Denton tectonic unit is unusual in that the intersection line of the roof thrust and floor thrust, on the northwest side of the structure, passes through the present erosion level. The structure section (S2C) passes just southwest of the point where this occurs. To the northeast, the floor thrust crops out, whereas, to the southwest, the fault trace bordered on the north by Sandsuck Formation rocks is the trace of the roof thrust.

Beds dip gently northwest on the external side of the Denton structure, and steepen toward the internal side (Hadley and Nelson, 1971, cross section B-B'). In the subsurface interpretation, the floor thrust remains close to the Blockhouse-upper Knox decollement horizon in its footwall. This is evidenced by the content of the cove windows, which indicate that the Great Smoky thrust overrides this horizon over a large distance of transport. In its hanging wall, the floor thrust climbs section, as constrained by the northwest dip of the beds and the flat or southeasterly dip of the floor thrust. The steeper dips at the internal edge of the Denton structure suggest that the floor thrust may climb section most rapidly in this area.

The same relationship holds between the roof thrust and the Denton slice beneath it. Probably, the roof thrust climbs section as steeply in the subsurface, rising from a lower decollement level in Precambrian strata. This is indicated by the high angle of the roof thrust to bedding at the internal edge of the structure.

The Denton slice has the geometry of a fragment plucked from a ramp as a thrust fault changes its position slightly, and incorporates some of the footwall into the upper plate. It was probably derived from the location, some distance to the southeast, where the Great Smoky fault climbs section from a level in Precambrian rocks (possibly the Sandsuck Formation) to the Rome Formation.

#### Great Smoky Plate (Footwall of Miller Cove Fault)

A minimum palinspastic overlap of 140 km is derived for the Great Smoky fault northwest of Chilhowee Mountain (5B-7B), based on interpretation of the COCORP seismic reflection profile. The prominent presumed Rome Formation reflector is identifiable on the COCORP line to that distance southeast of the Great Smoky fault trace. Since the Rome and strata below it are carried on the Great Smoky plate, that reflector must be missing in the region from which the thrust plate was derived.

The thrust plate between the Miller Cove fault and the Great Smoky fault is discontinuously preserved along the front of the Blue Ridge, and its largest cross-sectional area at any one time amounts only to about 7 square km (S5B). Only one major fold set appears to be present at the portion of the plate preserved on Chilhowee Mountain, whereas two fold sets cross one another at English Mountain.

A syncline with portions of its internal limb faulted out, stretches the length of Chilhowee Mountain. A small thrust plate (Bogle Spring, S5B) overrides the internal limb for 19 km of Chilhowee Mountain's 55 km length. It contains a complete anticline with an overturned forelimb, entirely in the Sandsuck Formation. At the northeast end of Chilhowee Mountain the synclinal axis has a southwest plunge, possibly accounted for by the southwest-dipping transverse step at Pigeon Forge, inferred in a previous part of this report.

English Mountain is affected by two fold trends (Greene, 1959). A N80W-trending anticline is present at the northeast end of the mountain. Its steep to overturned north forelimb is concordantly truncated at the base by the Great Smoky fault. The gently dipping south limb is overprinted by a N40E-trending syncline (S2C). The trend of the syncline is parallel to the trend of the Newport anticline to the southeast, and the internal limb of the Fair Garden anticline to the northwest. The syncline is concordant to the warping of the Great Smoky fault by those two anticlines.

#### Miller Cove Plate

A major syncline dominates the structure within the Miller Cove plate in the Richardson Cove area (S3C), and a major anticline may be present north of Tuckaleechee and Wear Coves (S6C), but polyphase deformation obscures the relationship between the areas.

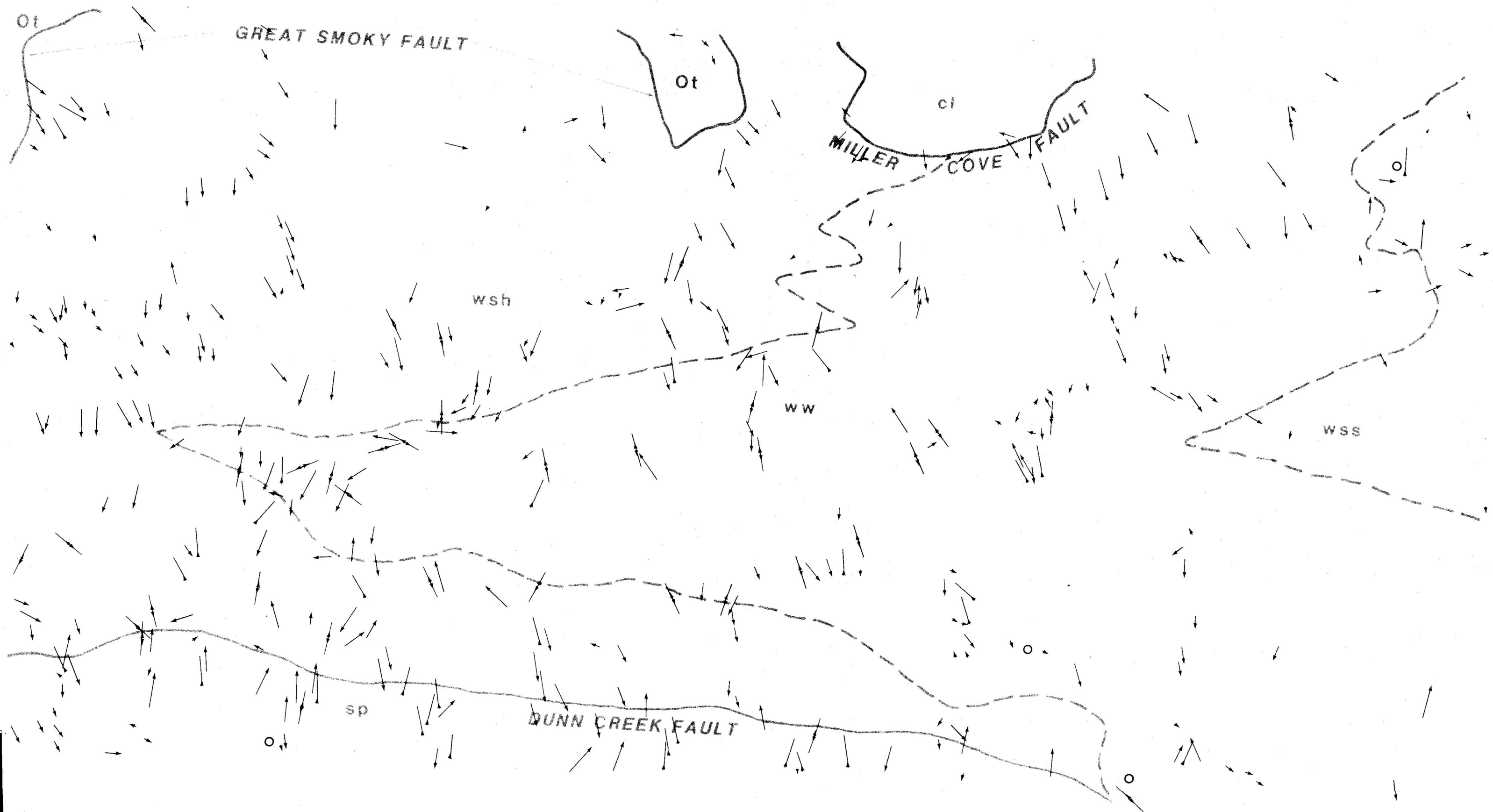
At Richardson Cove, beds dip gently southeastward at the external edge of the plate, and face northwest, dipping steeply, at the internal edge (fig. 5). The outcrop pattern shows a N65E trending, northeast

Figure 5. Dip arrow map, bedding in Miller Cove plate at Richardson Cove.

In this and following dip-arrow maps, arrows point in dip direction, and length of arrow represents amount of dip. Three-fourths inch equals 90 degrees dip. Arrows with head reversed represent overturned beds; the arrowhead points to the facing direction. Lines with no arrowhead, but dot in center, indicate vertical beds; strike is normal to length of line.

Solid lines with letters: fault. D: Dunn Creek fault. M: Miller Cove fault (Great Smoky fault in usage of Hamilton, 1961). G: Great Smoky fault (English Mountain fault in usage of Hamilton). Dashed lines: formational contacts in strata of Walden Creek group. Geology after Hamilton (1961).

Scale: 1: 24,000.



plunging syncline, with Sandsuck Formation in its core, cut obliquely on its internal edge by the Dunn Creek fault. Narrower outcrop widths on the southeast limb corroborate a steep sheet dip.

A possible anticline north of Tuckaleechee and Wear Coves, not recognized in structure sections of Neuman and Nelson (1965), is suggested by bed attitudes (fig. 6), and agrees with the stratigraphic assignments of Hadley and Nelson (1971). The axial trace of the proposed anticline would strike, on the average, about N60E, cutting across the Miller Cove plate at the approximate position of the Carr Creek fault proposed by Neuman and Nelson (1965). When psammitic rocks, north of Tuckaleechee Cove, first mapped as Wilhite formation (Neuman and Nelson, 1965) are reassigned to the Shields (Hadley and Nelson, 1971), the outcrop pattern also indicates an anticline along the same trend, with an axial depression midway across the Miller Cove plate, which separates the two outcrop areas of Shields Formation. At the Little Tennessee River (fig. 7; Neuman and Nelson, 1965; Livingston, 1977) an entirely northwest-facing stack of strata, possibly the external limb of the anticline mentioned above, fills the Miller Cove plate. Again, reassignment of "Wilhite, conglomerate member" to the Shields (Hadley and Nelson, 1971) produces an outcrop pattern that agrees with bed attitude information.

It is difficult to substantiate many of the faults mapped in the Miller Cove plate (King, 1964; Neuman and Nelson, 1965), solely on the basis of bed attitudes, but the Happy Hollow fault is an exception. It is a domain boundary that separates low-dipping strata with some northwesterly strikes from more steeply dipping, generally northeasterly



Figure 6. Dip arrow map, bedding in Miller Cove plate north of Tuckaleechee and Wear Coves.

Solid line at lower left: Great Smoky fault at northeast edge of Tuckaleechee Cove window. Solid line at top margin: Miller Cove fault. Solid line in middle: Happy Hollow fault. Shaded region, bounded by dashed line: outcrop area of Shields formation in sense of Hadley and Nelson (1971). Geology after Neuman and Nelson (1965) and King (1964).

Scale: 1:24,000

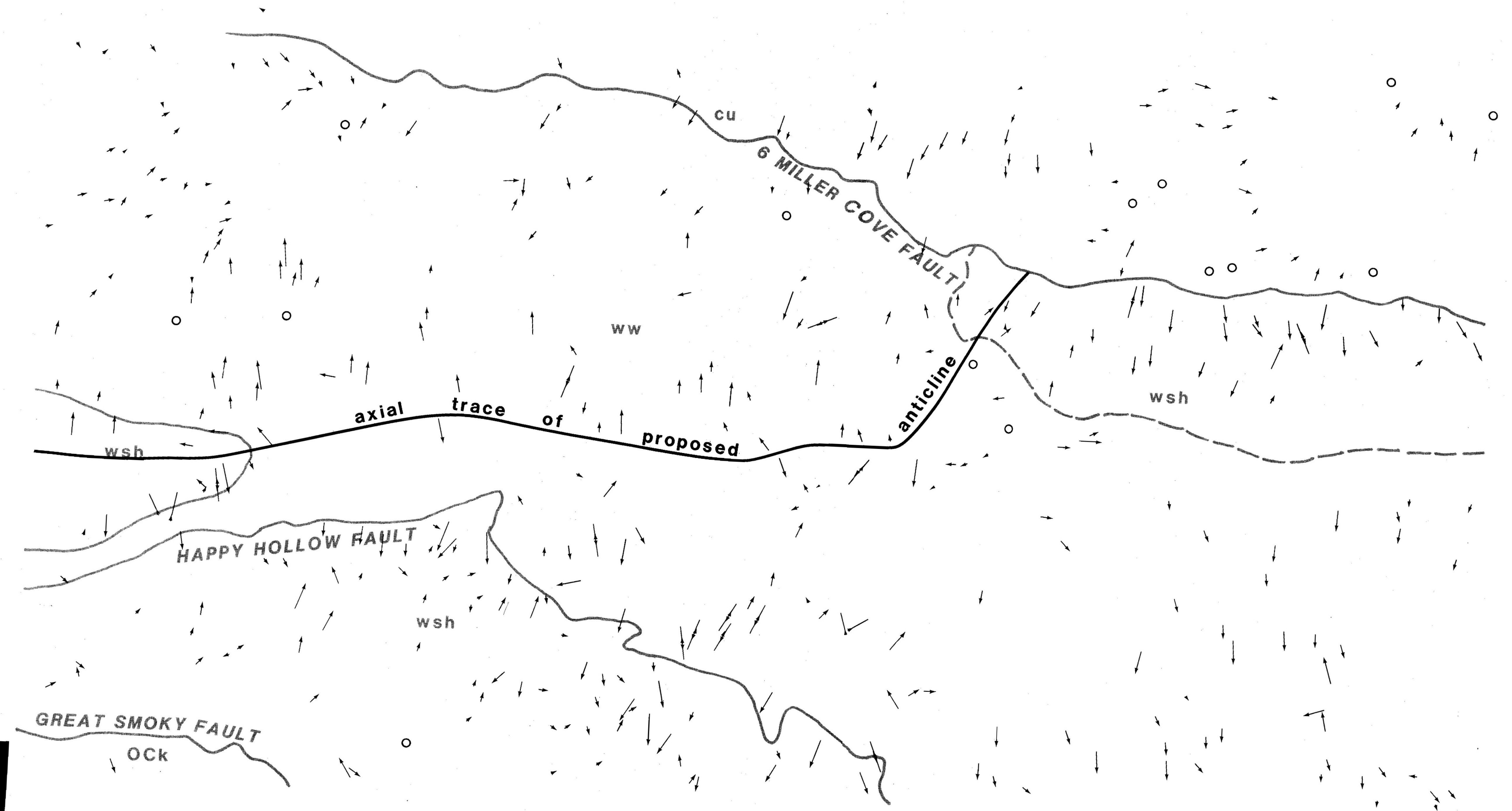


Figure 7. Structure along Little Tennessee River in the vicinity of Calderwood window (after Livingston, 1977).

Dashed lines: foliation.

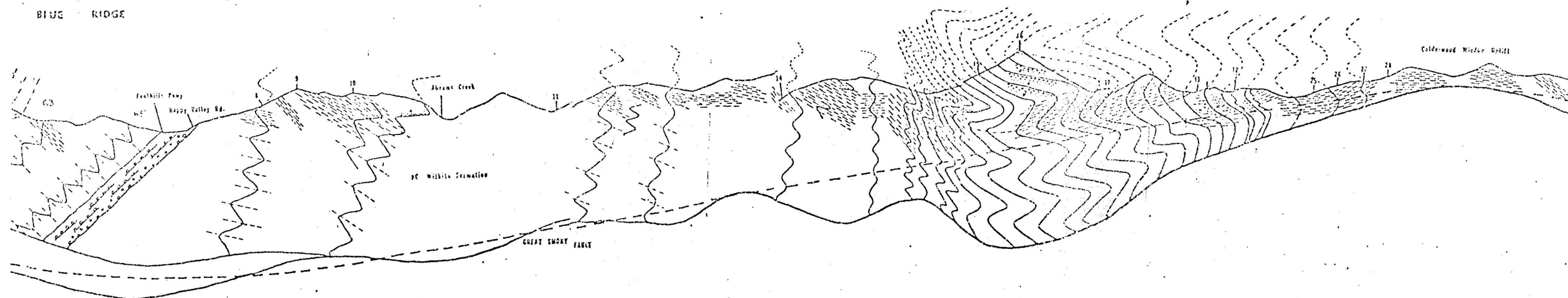


Figure 7.

striking rocks in the remainder of the Miller Cove plate to the north. The Happy Hollow fault brings up the lowest portion of the Walden Creek Group (Licklog and Shields formations), and cuts the major anticline to the north obliquely.

Foliation is approximately axial-planar to the major syncline at Richardson Cove and to the proposed anticline north of Tuckaleechee Cove. However, refolding of foliation is evident in much of the Miller Cove plate. Foliation dips are moderately southeast up to a point 4.6 km northwest of the Calderwood window (S7B) where dip quickly flattens (Livingston, 1977). Between this point and the window dip steepens once more, then flattens. Around Calderwood window foliation mimics the attitude of the Great Smoky thrust.

The attitude of foliation close to Tuckaleechee Cove and Calderwood windows seems to be affected by the up-arching which affects the Great Smoky fault. However, the angle between foliation and the probable attitude of the fault at depth varies considerably, suggesting that a pre-Great Smoky phase of postfoliation folding is also present. If the angle between foliation and the Great Smoky fault, observed near the window at Calderwood (Livingston, 1977) were constant, the Great Smoky fault would appear about 3.7 km north of Calderwood, which it does not.

Outcrop-scale features. Folds with axial-plane foliation are abundantly visible in most large outcrops of fine-grained Walden Creek strata in the Miller Cove plate. The folds trend northeast, and range in attitude from upright to recumbent, depending on the dip of foliation.

The form of the folds depends on the presence and thickness of competent sandstone interbeds. Rounded, open folds are developed where thick sandstone beds are present (Livingston, 1977; guidebook stop 7a), but folds with especially large ratios of amplitude to wavelength occur in thick sequences that are mostly pelitic (guidebook stop 1).

Veins, commonly ankerite but sometimes composed of various proportions of ankerite, calcite, chlorite, epidote, and quartz, are common in the folded sequences and bear all possible age relationships to the folds just described. In some folds, veins at a high angle to bedding are offset in a sense compatible with flexural-slip formation of folds (guidebook stop 7a). Slickensides also appear on bedding planes at some locations (Livingston, 1977; guidebook stop 1). They plot on a stereonet in a great circle about the fold axis, and steps indicate sense of slip compatible with flexural slip associated with folding.

Angular folds affecting foliation, commonly with wavelengths on the order of tens of centimeters, are upright horizontal folds with northeasterly trends (Livingston, 1977). At Cove Creek Cascades, these folds are parasitic to broad warps in foliation, visible in a large outcrop (guidebook stop 7b). Along the Little Tennessee River, these small-scale folds have axial-plane foliation which is locally stronger than the first foliation (Livingston, 1977).

Southeast-dipping thrusts affect rocks in the Miller Cove plate. They are contemporaneous with some postfoliation folds (guidebook stop 7a). Northwest-dipping kink bands typically less than 1 cm in width are common along the Little Tennessee River (Livingston, 1977).



### Dunn Creek Plate

From the Pigeon River to Murray County, Georgia, a fault trace marks the northwestern limit of Snowbird Group strata, and the southeastern limit of rocks unquestionably within the Walden Creek Group. The names Dunn Creek, Line Springs, Rabbit Creek, Sylco Creek, and Alaculsy Valley are applied to the fault along various segments, but only the name Dunn Creek is applied in this study.

Northeast of the Pigeon River (S1D-2D) both Snowbird and Walden Creek strata are present on both sides of the Dunn Creek fault. Outcrop widths and bed attitudes indicate considerable differences in the thickness of some units within the Walden Creek on opposite sides of the fault (Keller, 1980). On casual inspection, the Dunn Creek fault seems to have only minor displacement in this area, since it cores what appears to be a northwest-plunging syncline and only slightly offsets contacts of units. However, Keller (1980) concluded that the thickness differences indicate major displacement, and the apparent matchup of opposing limbs of a syncline is coincidental.

Structure at the French Broad River, a valley here largely in saprolite of Sandsuck Formation or covered by alluvium, is difficult to interpret. External to the Brushy Mountain fault, several faults are present on either side of the river (Ferguson and Jewell, 1951; Keller, 1980). On both sides of the river, the most internal thrust sheet carries no strata higher than the Sandsuck formation. The more external tectonic units contain the overlying Chilhowee, Shady, and Rome strata. The writer suggests correlation of the two most internal faults, the

Dunn Creek and the Buffalo Rock thrusts, with the connecting portion coinciding approximately with the French Broad River. Keller (1980 and pers. comm.) holds that this interpretation cannot be borne out by mapping. Instead he correlates the Dunn Creek fault with a more external fault north of the river, the Yellow Springs Mountain fault.

The internal limit of the Dunn Creek plate is defined as the Brushy Mountain fault near the French Broad River, but becomes more difficult to identify further southwest. Keller (1980) extended the Brushy Mountain fault to the Pigeon River. Near the Pigeon River the fault brings Roaring Fork Sandstone (Snowbird Group) on Roaring Fork Sandstone, and the fault is mapped on the basis of photolineaments, and a contrast in metamorphic grade (chlorite vs. biotite zone) and textural alteration. As mapped by Keller (1980), the fault can be projected from the Pigeon River into an unnamed fault mapped by Hadley and Goldsmith (1963), which merges northward with the Gatlinburg fault. West of the point of merging, location of the Brushy Mountain fault trace is conjectural. A possibility suggested by Keller (1980) is that the fault forks southward again from the Gatlinburg fault, as the Snag Mountain fault, which merges with the Greenbrier fault on the slopes of Greenbrier Pinnacle. The fault would coincide with the Greenbrier as mapped by Hadley and Goldsmith (1963) and King (1964), this point at least as far west as Fighting Creek Gap (S4C-5C).

However, the Gatlinburg fault is itself a domain boundary in this area, and is close to or may coincide with the biotite isograd as mapped by Hadley and Goldsmith (1963) and King (1964). Based on these admittedly

loose constraints the writer brings the Brushy Mountain thrust to Fighting Creek Gap via the Gatlinburg fault.

On the tectonic map (Plate 3) the writer has indicated a hypothetical trace of the fault from Fighting Creek Gap southeast, mostly within the Great Smoky Group. A domain boundary is suggested on dip-arrow maps corresponding to the contact (S5C) between the Thunderhead and Elkmont formations (King, 1964); the hypothetical fault trace follows this contact and is projected southwestward into the "fault of Nichols Cove" (S7C) mapped by Lesure et al. (1977), and the Sassafras Ridge thrust (S8C) proposed by Poppelreiter (1980). The projection of the Brushy Mountain trace a considerable distance from the area where it has been mapped was done mainly to simplify relationships between adjacent cross sections. Based on the presumed similar amounts of shortening in adjacent sections, it is likely that one or more major unmapped thrusts are present in the Great Smoky Group in the area where the fault has been projected, but the real pattern is probably more complex than the sections and tectonic map suggest. Because of monotonous stratigraphy and limited exposure, the structure may never be resolved unequivocally.

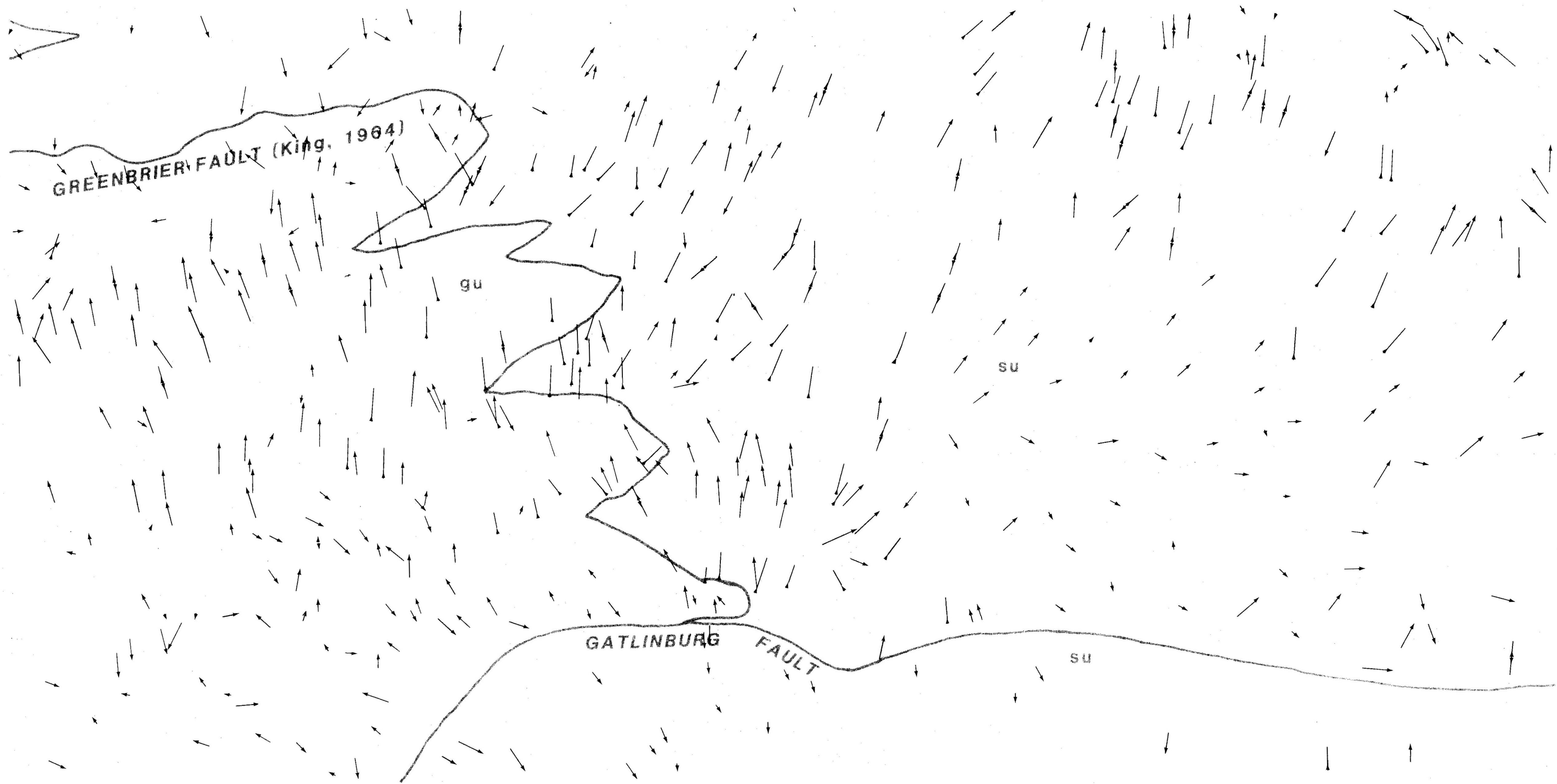
From the east end of Webb Mountain to Cove Mountain tower (S3C-5C) the area between Dunn Creek and the Gatlinburg faults is dominated by a syncline, with only a narrow portion of the moderately south-dipping forelimb of the syncline preserved at the north edge of the plate (fig. 8). The backlimb of the syncline generally is steep. West of Cove Mountain Tower (S5C), the moderate southeast dips of the forelimb continue, but the steep northerly dips of the backlimb give way to an

Figure 8. Dip arrow map, Dunn Creek plate in the Gatlinburg vicinity.

Solid line: Gatlinburg fault. Dashed line: eastern limit of Great Smoky group rocks of Cove Mountain, as mapped by King (1964). Geology after King (1964).

Domain of east dips near east end of illustration is matched, south of Gatlinburg fault, about 4 km further east.

Scale: 1:24,000.



area of diverse dips, many of which are easterly. At Metcalf Bottoms (S5C), the entire width of the plate is dominated by moderate southeast dips, but farther west, south and west of Tuckaleechee Cove (S6C), the southeasterly dipping region becomes the backlimb of an anticline, as steep northwesterly dips take over the external edge of the Dunn Creek plate.

A small portion of the Dunn Creek plate mapped by Lesure et al. (1977) contains a north-trending syncline which terminates against the "fault of Nichols cove" (8; S7C; correlated in this study with the Brushy Mountain fault). Along Tellico River (S8C), the Dunn Creek plate is dominated by a syncline with moderately dipping forelimb, and steeply dipping backlimb, and axial plane cleavage.

Correlation in the Dunn Creek plate between structure judged from bed attitudes and the outcrop pattern, is poor. In particular, beds strike normal to, and give no hint of a structural domain boundary at, the irregular eastern limit of massive coarse sandstones east of Cove Mountain (S4C). The northern limit of the same sandstone facies is parallel to the strike of beds, but appears a short distance north of what ought to be the axial trace of a syncline. The complicated system of faults proposed in the geologic map of the Gatlinburg quadrangle of King (1964) does not account for the continuity of fabric domains across the contact, so it does not appear in S4C. However, the alternative of a facies transition between massive sandstones and pelites, which in places needs to have been nearly vertical over kilometers of section, is almost as problematic.



The clearest change of foliation attitude in the Dunn Creek plate is in Richardson Cove (S3C). Near the Dunn Creek trace, foliation dips steeply southeast. It becomes gentle in the central portion of the place, and steepens again close to the Gatlinburg fault. The gently dipping portion of this fold in foliation is on trend with the axis of the Newport anticline. The subsurface interpretation (S3C) shows a small duplex structure interpreted as the down-plunge continuation of the duplex which warps the Great Smoky fault around Newport.

In the Gatlinburg area (S4C), a set of upright subhorizontal folds with east to northeast-trending axes are overprinted by a set of steeply southeast-plunging inclined folds (guidebook stops 9, 10, and 12). Cleavage is axial planar to the later set. This agrees with Hamilton's (1961) observation from Richardson Cove that cleavage strikes more northeasterly than the east-trending folds that dominate structure in that portion of the Dunn Creek plate.

Like folds with axial-plane foliation which are developed in the Miller Cove plate, the steeply plunging folds have slickensides on fold limbs, which plot in a great circle around the fold axis, and whose sense is compatible with flexural slip during folding. On east-trending fold limbs, this sense is a combination of reverse and right-lateral. King (1964) described similar slickensides from the Gatlinburg area, from which he drew the conclusion that slip on the nearby Gatlinburg fault is a combination of reverse and right-lateral. Perhaps the slickensides King observed have nothing to do with the Gatlinburg fault. The macroscopic data seems to indicate left-separation (fig. 8) for the Gatlinburg fault.



In the area between Metcalf Bottoms and Townsend (S5C-6B), reclined southeast-trending folds are observed in exposures of Metcalf phyllite (fig. 9A; guidebook stop 4a). The folds have axial-plane foliation, and are tight and generally angular. No prefoliation folds are observed in this area. Stereonet plots of bedding (fig. 9B) suggest that the southeast-plunging fold geometry dominates in this area, but macroscopic reclined folds have not been mapped.

Foliation is commonly cut by kink bands, typically northwest dipping, which range from 1 to 15 mm in width. A single outcrop may have up to three sets of kink bands, each with a different morphology. Kinks differ on the basis of width, degree in which orientation wavers and anastomoses with other kinks, and darkness relative to surrounding rock.

A few planar kink bands are parasitic to sharp hinged folds reported by King (1964). The chevron folds (guidebook stop 3) are up to 10 cm in amplitude and up to 20 km in wavelength. Axes are consistently subhorizontal and trend S10W to S30W (fig. 9D). A very weak crenulation cleavage, typically visible in outcrop only as an intersection lineation on foliation surfaces, is axial planar to these folds.

In portions of the Metcalf phyllite area of outcrop, particularly those close to the trace of the Great Smoky fault along the edge of Tuckaleechee Cove (S6B), another kind of kink fold (shear cleavage of King, 1964) dominates the structure seen in outcrops (guidebook stop 5). Axial planes of these kinks range in dip from northwest through horizontal to southeast (fig. 9C), and are sometimes broken by faults of small displacement. Regardless of the attitude of axial planes, the

Figure 9. Equal-area projection of axes of fabric elements, Dunn Creek plate south of Tuckaleechee and Wear Coves.

A. Axes of folds with axial plane foliation. Solid line contours at 12, 17 and 21% of total data points per 1% area. Dashed lines contour at 8%. Twenty-four fold axes measured.

C. Poles to axial planes of kinks, called "shear cleavage." Solid line contours at 9, 11, and 14% of total data points per 1% area. Dashed line contour at 6%. Thirty-five fold axes measured.

D. Axes of folds affecting foliation, near guidebook stop 2. Solid line contours at 7, 9, and 14% of total data points per 1% area. Dashed line contour at 5%. Forty-three fold axes measured.

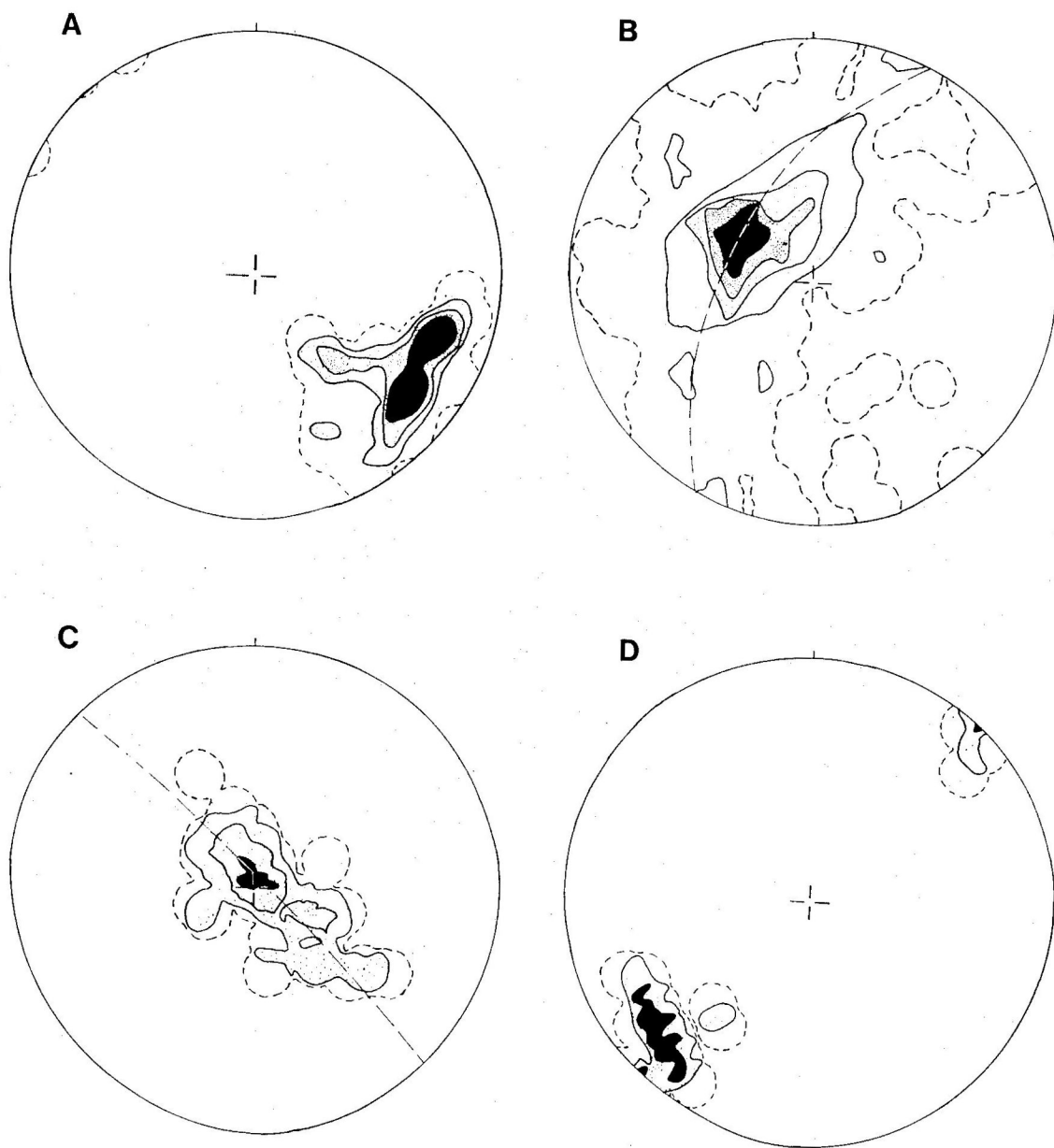


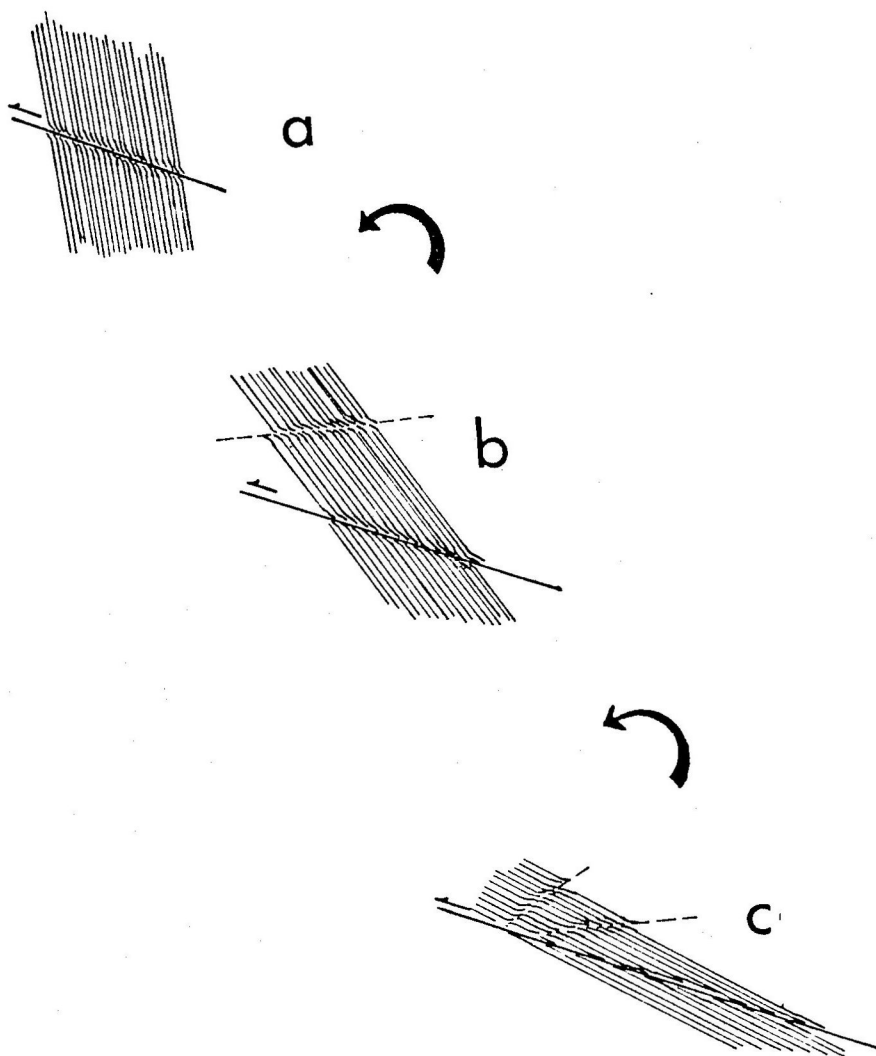
Figure 9.

asymmetry of the kinks and offset of quartz veins on the associated faults indicate relative movement of the upper block approximately toward the northwest. Since this sense of movement precludes kinks of opposite dips being conjugate, the fabric is interpreted to have been produced during rotation of foliation from a steep dip to a gentle southeast dip (fig. 10). Kinks now dipping northwest were formed with a subhorizontal orientation while foliation dipped steeply southeast, and therefore were produced earliest. The kink fabric is interpreted as a consequence of a field of subhorizontal simple shear, which, on a larger scale, was rotating foliation from a steep attitude to a gentle one. The simple shear is in the same sense as, and is presumably related to a stage of, thrusting on the Dunn Creek-Great Smoky fault not far beneath.

### Brushy Mountain Plate

The Greenbrier fault, probably of early Paleozoic age, separates the Brushy Mountain plate into two tectonic subunits, which are dealt with separately in the discussion below.

Footwall of Greenbrier fault. Southwest of the Hot Springs window (D-2E) the Brushy Mountain plate bears a steeply dipping, north-facing sequence of late Precambrian strata which overlie billion-year old basement. This geology is projected into section 1 (S1D-1E). On the southern side of the Hot Springs structure, the Brushy Mountain fault coincides with the roof thrust (interpreted as the Great Smoky fault). The location where it branches away from the Great Smoky fault is eroded in the line of section 1.



### Development of shear fractures

Figure 10. Proposed rotational origin of kinks called "shear cleavage."

Southeast is to the right. The active surface of slip or kinking (solid line with half arrow indicating sense of movement) maintains a constant dip of about 35 degrees to the southeast, as foliation (closely spaced lines) rotates from a steep to a gentle dip.

A southwestward-widening region of gently southeast-dipping strata between the steep north-facing beds and the external edge of the Brushy Mountain plate (S1D-2D) makes up the forelimb of the Waterville syncline (Keller, 1980). The syncline is tightest approximately along the Pigeon River (S2D). The southwestward continuation opens out considerably, taking on a southwest plunging form concordant to synclinal folding of the overlying Greenbrier fault.

The Greenbrier fault brings basement on basement somewhere south of the line of section 1, where its trace has not been mapped. The structure immediately in the footwall of the Greenbrier fault is poorly known between sections 1 and 2. Further southwest (S2E-3E), the Greenbrier fault overrides late Precambrian metasediments, and an anticline with considerable structural relief (Cataloochee anticlinorium) has been mapped (Hadley and Goldsmith, 1963). A steep reverse fault, the Cold Springs fault, cuts the back limb of this structure just southeast of the hinge area. Both the Cataloochee anticline and the Cold Springs fault affect the Greenbrier fault (Hadley and Goldsmith, 1963).

Attitudes of foliation indicate a polyphase deformation history in this structural subunit. Foliation appears to be axial-planar to the tight syncline (Waterville syncline) at the external edge of the Brushy Mountain plate (S2D; Keller, 1980). However, dip of foliation, and of axial planes of folds parasitic to the syncline, changes from nearly vertical in the northwest to moderately southeasterly near the sediment-basement contact. In other words, an open syncline affecting foliation is present which adds to structural relief produced by the first syncline.

Figure 11 shows a section along line B-B' of Hadley and Goldsmith (1963). Foliation is folded in an open syncline which mimics geometry of the folded Greenbrier fault. On the north limb of the Cataloochee anticline, foliation in the footwall of the Greenbrier dips steeply to the northwest. Dip decreases toward the hinge area, and the southeast limb of the Cataloochee anticline contains southeasterly dipping foliation.

A dip-arrow map between the two sections (fig. 12) shows that the northwest-dipping foliation in the B-B' section is on strike with moderately southeast-dipping foliation of section 2, and the change between the two attitudes is gradual. Figure 12 shows dip-arrow maps of foliation and bedding for a portion of the southwest-plunging syncline which is concordant to the Greenbrier fault, identified as the continuation of the Waterville syncline (Keller, 1980). It indicates that foliation rotates in average strike slightly southwest of the early synclinal axis of section 2, mimicking the rotation in strike of bedding, just as decrease in dip of foliation mimics decreasing dip of beds. The writer suggests that folding of the Greenbrier fault mainly postdates foliation. Clearly the Cataloochee anticline and Cold Springs fault postdate foliation; the case for the open, southwest-plunging syncline further northwest is admittedly not as certain, since it seems to be continuous into the Waterville syncline which has axial plane foliation.

Hanging wall of Greenbrier fault: bedding. The Alum Cave syncline, trending about N80E, dominates the structure between Mount Guyot and



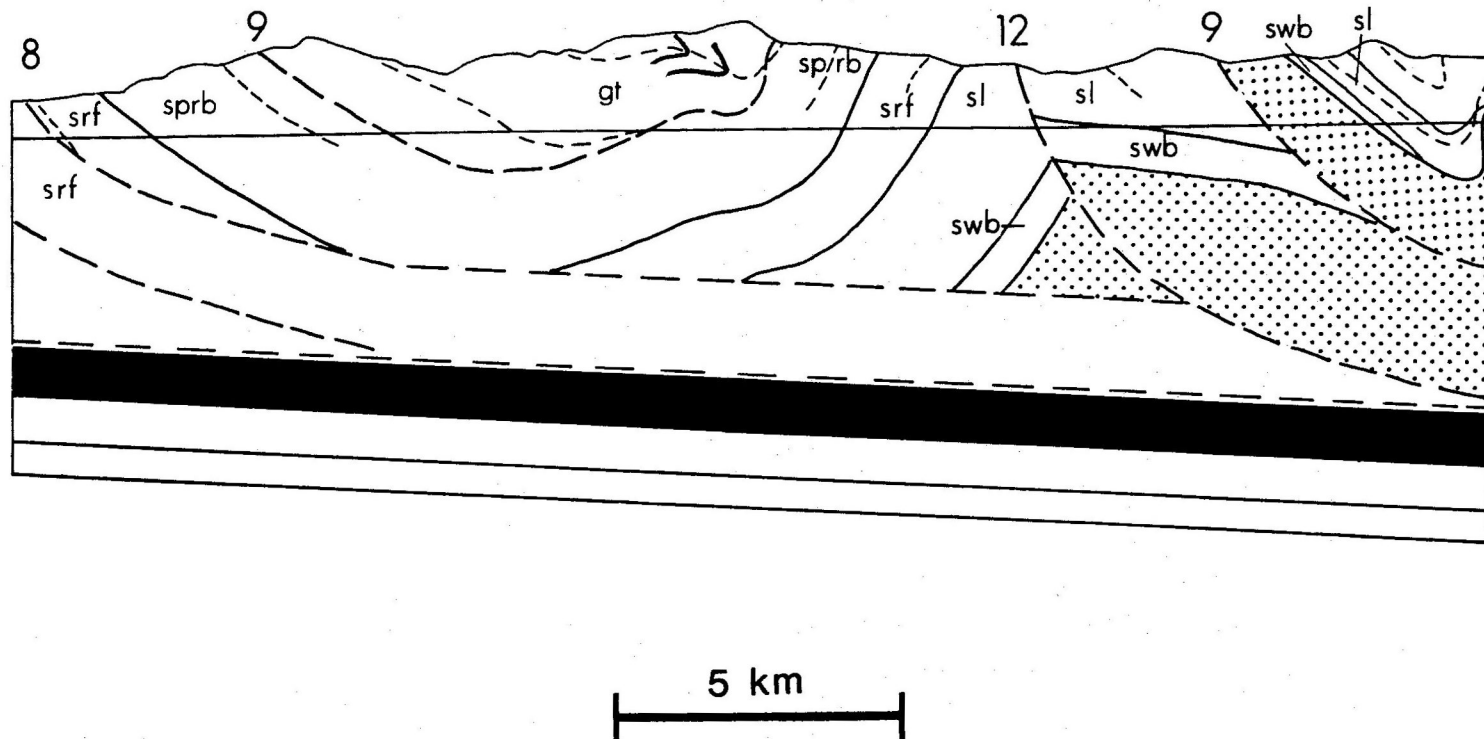


Figure 11. Northeasternmost end of Greenbrier thrust sheet, and footwall, in cross section.

Section (not a detail from Plate I or II) along line B-B' of Hadley and Goldsmith (1963). Line of section shown in fig. 12. Syncline within Greenbrier thrust plate that does not appear to affect foliation may be continuation of Alum Cave syncline. Refolding of foliation is due to Cataloochee anticlinorium, which also affects Greenbrier fault.

Figure 12. Dip arrow map, bedding and foliation in Brushy Mountain plate in Pigeon River area.

Heavy arrows: foliation. Light arrows: bedding. Heavy lines: fault traces.

Formational contacts within Snowbird group (thin lines) outline concordant folding of beds and Greenbrier thrust plate.

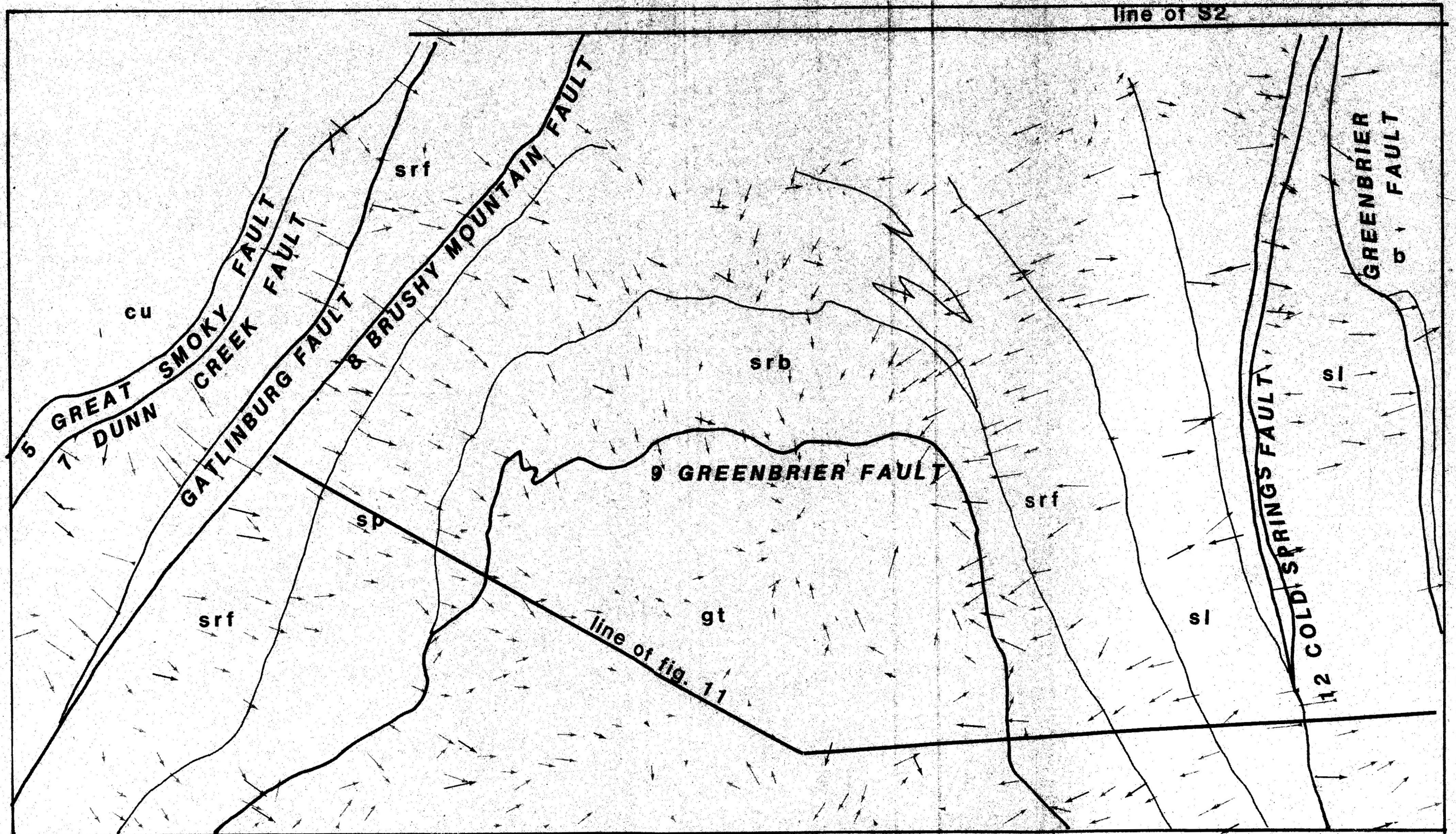


Figure 12.

Mount LeConte in the eastern Great Smokies (S3D-4D). It has a gently dipping north limb and a vertical to overturned southeast limb.

The Ravensford anticline (S3C-5D), cored by outcropping Snowbird group and basement, is only 5.6 km southeast of the axial trace of the Alum Cave syncline, close to Mount Guyot. The outcrop area of Snowbird Group and basement trends about N40E, and has a blunt termination at the northeast end, only 2.6 km across strike and 5.6 km along strike from the trace of the Greenbrier fault, on the northwest limb of the Cataloochee anticline discussed previously.

Because the Alum Cave syncline and Ravensford anticline have different strikes, the area between them widens westward. Immediately south of the Alum Cave syncline (S4D) is an anticline parallel to its trend; together the structures have a relief of more than 5 km. The remainder of the area (S4D-5E) is dominated by folds parallel to the Ravensford structure, but lower in amplitude. Basement emerges in the core of two anticlines, at the Bryson City and Ela domes (S5E).

The Fie Creek anticline (S3E-5E) is about 19 km to the south of the Alum Cave syncline, and is roughly parallel to it. The Fie Creek intersects the Ravensford anticline at Cherokee, N.C. Basement and rocks of the Snowbird Group are exposed in the core of the Fie Creek anticline. The Ela and Bryson City domes, just west of Cherokee, are located on the intersection of N40E anticlines with the projection of the Fie Creek trend. An en echelon outcrop pattern of the basement-sediment contact also occurs southeast of the Ravensford anticline (S4E-5E), where folds of N40E trend intersect the Fie Creek structure.



The Murphy syncline dominates the outcrop pattern of the Greenbrier thrust sheet southwest of section 5 (S6-8,D-E). It has more than 8 km of structural relief. The lowest stratigraphic unit which helps to define location of the syncline is a sequence of dark, fine-grained clastics assigned by Hadley and Goldsmith (1963) to the Anakeesta Formation. These rocks are stratigraphically about 2.8 km above basement (S6E).

A fault or major ductile deformation zone northwest of the Bryson City dome (S5E-6E) is implied by the fact that only 0.5 km separate basement exposures of the Bryson City dome from these fine-grained strata.

The outcrop widths of strata coring the Murphy syncline diminish, and the nose of the structure acquires a squared-off shape, southwest of Bryson City (S6E-7E).

The Murphy syncline opens out considerably northeast of Murphy (S7-8,D-E).

The northwest limb of the Murphy syncline, from section 6 at least as far southwest as Mineral Bluff, Georgia, contains overturned, southeast-facing beds. Further northwest (S7D-8D), the hinge of the Robbinsville anticline is parallel to the trend of the Murphy structure, and beds dip gently northwestward. The axial trace of an open syncline (S7C-8C) separates these northwest-facing beds from the gentle southeastward dips which characterize the external edge of the Brushy Mountain plate from section 3 through section 8 (S3C-8C).

Forrest (1975) mapped the Murphy syncline near Murphy, N.C. (S8E), where the outcrop area of the Murphy belt group (informal designation;

Kish et al., 1975) widens considerably. No structure sections accompany his study, but a tectonic map suggests that the major structure in the area consists of northeast-trending isoclinal folds of an early generation (Murphy syncline and Valley River anticline) refolded around upright second generation folds which have approximately the same trend. Hatcher (1978), who quotes Forrest, drew a cross section across the area which shows a simpler geometry of the Murphy syncline than Forrest's tectonic map suggests. Although both limbs are nearly vertical, the sheet dip in the core is subhorizontal across most of the outcrop area of the Murphy belt group. The writer used Forrest's geologic map data to construct section 8 across this area, and was likewise unable to honor the interpretations suggested in Forrest's tectonic map. S8E is instead similar to Hatcher's cross section.

Forrest's isograds are plotted on section 8. They are drawn to depth on the basis of two simplifying assumptions: that isograd surfaces are parallel and the separation between biotite and staurolite isograds is 1 km (based on a temperature difference of 25 degrees at a thermal gradient of 25 degrees C/km). Although this is a crude model of thermal structure, the conclusion that relief on the isograds is little different from relief on bedding estimated in section 8 (and in the section of Hatcher, 1978) would appear reasonable. This suggests that in this line of section, the major syncline postdates the peak of metamorphism. The same is probably not true in sections along strike to the southwest (e.g., Hurst, 1955), where all units in the Murphy syncline are reported to be at staurolite grade or higher. There is an apparent contradiction,

therefore, in the age of the major syncline relative to metamorphism in the two areas. A possible explanation is that two separate synclines exist, probably of different ages, which overlap one another, and the broad syncline near Murphy is only obvious from the outcrop pattern when the narrow isoclinal syncline of the southwesterly area fades out.

A major structural problem is the failure of basement to emerge at the expected stratigraphic level on the northwest limb of the Murphy syncline (S6D-8D). The following are possible explanations:

1. The basement contact exposed southeast of the Murphy syncline is not a stratigraphic contact, but a thrust fault. This is an interpretation proposed by Kish et al. (1975), who extended Hadley and Goldsmith's (1963) identification of the basement-sediment contact around the Ravensford anticline as the Greenbrier fault, to all basement-sediment contacts in the area. There are problems with balancing this interpretation. In general, such a fault must cut considerably down section in the upper block towards the north.

In the specific case of the Ravensford anticline contact, the northeast end of basement exposure is only 2.6 km from the main trace of the Greenbrier (S2-3D-E; fig. 11, page 64) where the fault is riding, bedding-parallel, high in the sedimentary section. The Hadley and Goldsmith (1963) interpretation seems to imply an abrupt change in the kinematic relation of the Greenbrier thrust to structures in its footwall, over a rather short distance along strike. The writer favors an alternative interpretation, namely that the contact around the Ravensford anticline is pre-Greenbrier, and was up-arched significantly prior to Greenbrier thrusting.



A novel solution to the down-section northward geometry of the fault in this hypothesis would be that thrusting was south-directed. This is considered weaker than the third alternative, below, since no southeast-directed thrusting phase has been identified in this part of the Blue Ridge.

2. The basement-sediment contact southeast of the Murphy syncline is a stratigraphic one, but it drops relative to the section as one goes northwest. At least 5.5 km of descent is required over an unfolded width of perhaps 45 km. This could be accomplished if sediments west of the Murphy syncline were deposited in a graben; however, sedimentary thickness of 10 km+, estimated relative to the level of the basement southeast of the Murphy, is already a little unusual, and a greater thickness might be a problem. Also, no major normal faults have been mapped in the Great Smokies so far, except a late feature near Cherokee.

3. The location northwest of the Murphy syncline where basement is expected is only apparently at the same level as basement exposures on the other limb of the syncline. The section is duplicated by thrust faults, as yet unmapped, which emerge on the northwest limb of the Murphy syncline. This is the interpretation adopted (S6-8, C-D).

Hanging wall of Greenbrier fault: foliation. Foliation is unaffected by the Alum Cave syncline, the unnamed anticline just south of it (S4D), the Fie Creek anticline, and the Murphy syncline. The last two structures are considered coeval with foliation (Hadley and Goldsmith 1963; Kish et al., 1975), whereas the first two may be coeval with, or

earlier than, foliation. Many of the remaining major structures in the Greenbrier thrust sheet refold foliation.

The Ravensford anticline and several N40E-trending structures to either side of it (S3-4, D-E) affect foliation. The Bryson and Ela domes may result from interference of such folds with the Fie Creek anticline. Folds trending N40E, east of Cherokee (S4E-5E), which tightly fold foliation, produce an en echelon outcrop interference pattern on the north limb of the Fie Creek anticline. Finally, tight folds affecting foliation are present southeast of the Fie Creek anticline (S3F-5F) and have been mapped in detail in the Dellwood quadrangle (S3F).

Foliation in the basement coring some of these structure typically is parallel to foliation in the sediments and shows the postfoliation fold patterns equally well. An apparent exception is basement coring the Ela dome (S5E) in which foliation dips steeply away from the hinge on the limbs of the structure, but is vertical in the core of the fold. The vertical foliation may be explained as a second-generation foliation which obliterates the main foliation close to the hinge region.

In the core of the Ravensford structure itself, sediments appear to be isoclinally in-folded into basement (S3D-3E), by folds which affect foliation. Axial planes of these folds rotate across the outcrop area of basement and Snowbird Group. The Snowbird-basement contact on the southeast side of the area of basement outcrop changes along strike from northwest-dipping through flat to southeast dipping as the hinge of the late warp is obliquely crossed.

The Robbinsville anticline is a postfoliation structure with a steep to overturned southeast limb and a gentle northwest limb, which dominates

structure northwest of the Murphy syncline. It is open, if it is present at all, in the line of section 6, but it tightens along strike to the south (S7D-8D). This structure has so large a structural relief that it must predate Great Smoky thrusting: it is too big a structure to form in the available space above the Great Smoky during thrusting, and it would bring the Great Smoky thrust to the surface if it postdated thrusting.

The dominant foliation has different ages relative to the peak of metamorphism in different parts of the Greenbrier thrust sheet, according to the writer's interpretation. The Murphy syncline and Fie Creek anticline both have axial plane foliation, which is evidently the earliest and strongest foliation in each area.

Isograd mapping (Forrest, 1975) suggests that, in the area of Murphy, the Murphy syncline postdates the peak of metamorphism, bringing biotite zone rocks to the same plane as staurolite zone rocks (S8E).

The Fie Creek folding was succeeded by other structural events predating the setting of isograds. Isograds cross the Greenbrier fault unaffected. The timing of the Ravensford anticline relative to the Greenbrier is of key importance. Hadley and Goldsmith (1963) concluded that basement and a 1.5 km thick cover of Snowbird Group, which crop out in the core of the Ravensford anticline (S3D-3E) represent material in the footwall of the Greenbrier fault, exposed in a window. As explained above, the writer prefers the interpretation that the Ravensford anticline does not warp the Greenbrier, and the contact in the core is the depositional base of Ocoee sediments. This in turn constrains timing

of the Fie Creek anticline and its axial plane foliation, which are affected by the Greenbrier and associated structures. The whole sequence of events predates regional metamorphism.

### Timing of Structures

Table I summarizes constraints on relative timing of structures in the Blue Ridge. Structures are placed in sequence relative to metamorphism and to Great Smoky faulting.

### Metamorphism

Age of metamorphism is indicated by Rb-Sr dates (Kish et al., 1975) on pegmatites of around 440 million years before present (abbreviated m.y.) and K-Ar ages on metamorphic rocks ranging from 470 to 320 m.y. (S. A. Kish, pers. comm.). The K-Ar ages decrease systematically southeastward across the Blue Ridge, with increasing metamorphic grade. Because K-Ar ages represent final cooling of rocks below a fairly low (approximately 300 degrees C) temperature, at which diffusion of argon out of the system becomes vanishingly slow, the younger ages in the higher rank rocks indicate longer time necessary for cooling (Armstrong, 1966). Prior to the setting of the K-Ar ages and after rocks had heated up past the threshold of the greenschist facies, diffusion of silica and other components may have been fast enough to permit development of foliations as strain accompanied folding.

Any foliation in the Blue Ridge which involves dissolution of silica and precipitation of microscopically visible layer silicates (referred to herein as metamorphic foliation) is probably broadly syn-metamorphic.

TABLE I  
SUMMARY OF MAJOR STRUCTURES IN BLUE RIDGE

| Name or Symbol  | Trend | Range of Possible Ages<br>(relative) |      |
|-----------------|-------|--------------------------------------|------|
| [METAMORPHISM]  | --    | XXXX                                 |      |
| Great Smoky F.  |       |                                      | XXXX |
| A               | 60    |                                      | XX   |
| B,C             | 30    |                                      | XX   |
| D               | 65    |                                      | XXXX |
| E               | 20    |                                      | XXX  |
| F,G             | 35    | XXXXXXXXXXXXXXXXXXXX                 |      |
| H,I             | 20    |                                      | XXX  |
| J               | 40    | XXXX                                 |      |
| K               | 25    | XXXX                                 |      |
| L               | 30    |                                      | XXX  |
| M               | 35    |                                      | XXX  |
| N               | 45    | XX                                   |      |
| Cartertown A.   | 65    | XX                                   |      |
| P               | 40    | XXXX                                 |      |
| Q               | 50    |                                      | XXX  |
| R               | 30    | XXXXXXXXXXXXXXXX                     |      |
| S               | 25    | XXXX                                 |      |
| Waterville S.   | 20    | XXXX                                 |      |
| U               | 20    | XXXX                                 |      |
| V               | 15    | XXXXXXXXXXXXXXXX                     |      |
| Cataloochee A.  | 15    | XXXXXXXXXXXXXXXX                     |      |
| Alum Cave S.    | 45    | XXX                                  |      |
| Y               | 45    | XXX                                  |      |
| Z               | 10    | XXXX                                 |      |
| Robbinsville A. | 35    | X                                    |      |
| b               | 0     | XXXXXXXXXXXXXXXX                     |      |
| c               | 30    | XXX                                  |      |
| Murphy S.       | 25    | XXX                                  |      |
| Valley River A. | 35    | XXX                                  |      |
| Fires Creek S.  | 40    | XXX                                  |      |
| Fie Creek A.    | 50    | XX                                   |      |
| h               | 20    | XX                                   |      |
| i               | 20    | XX                                   |      |
| Ravensford A.   | 10    | X                                    |      |
| j-s             | 15    | X                                    |      |
| Greenbrier F.   | --    | X                                    |      |

Development of foliations was evidently not due to rises in temperature or deviatoric stress that can be correlated regionally, but rather to local formation of folds during the relatively long period of time during which temperature and fluid availability permitted foliation development. This is why distinct phases of deformation (D1, D2, D3 . . .) are evidently not applicable over so large an area of study. For example, the dominant foliation in the Murphy area is unaffected by the major Murphy syncline, which, in the Murphy area, may be younger than setting of isograds (p. 69), whereas the dominant and earliest foliation, axial planar to the Fie Creek anticline, appears considerably older (p. 67, 72).

The evidence of Armstrong (1966) implies that a longer period of time was favorable for metamorphic foliation development in southeasterly areas relative to more external regions. In the internal region of the study area, any fold with axial plane foliation is interpreted to have formed in the neighborhood of 470 to 320 m.y., whereas structures with foliation in external, lower-rank rocks are restricted to a much shorter time span, in the neighborhood of 470 m.y. In theory, it may be uncertain whether absence of axial plane foliation implies a fold formed outside the period of metamorphism, although this is a common assumption (e.g., Keller, 1980).

#### Great Smoky Fault

The Great Smoky fault crosscuts structures related to movement on the Guess Creek fault (p. 28). The Guess Creek overrides Mississippian strata, and belongs to the Valley and Ridge thrust system which involves rocks as young as early Pennsylvanian. Post-Great Smoky structures are



therefore Carboniferous or younger. The writer knows of no upper limits on Great Smoky faulting that establish it as beginning after metamorphism. Structures postdating the main foliation, but earlier than Great Smoky faulting, can be established in the Miller Cove plate; however, there is no certainty that the structures postdate metamorphism.

The duration, if any, of the gap in Table I between metamorphism and Great Smoky thrusting is unknown. Possible age spans of folds are assigned on the basis of relationship to metamorphic foliations and to Great Smoky thrust geometry. Within the time span of metamorphism in the table, relative ages are assigned in relationship to the setting of isograds, and to the Greenbrier fault.

### Conclusions

The attempt to construct balanced regional cross sections has shed light on several structural problems in the study area.

Between English Mountain (S2C) and the Little Tennessee River (S7B), the front of the Blue Ridge seems influenced by a major ramp in the subsurface. This ramp is believed to represent the ascent of the Saltville fault from the master decollement to a higher detachment position. A transverse step at Pigeon Forge (S4B) is suggested.

The backlimb of the Notchy Knobs syncline (S8B) in which middle Cambrian strata crop out in the footwall of the Great Smoky fault, poses a difficulty for structural interpretation. The thin-skinned solution which appears most plausible postulates an unmapped thrust, of about 20 km displacement, which must crop out in the forelimb of the Notchy Knobs syncline.

Published mapping, largely reconnaissance, suggests that in several locations (S2C, S5C-6C, S8B), the Great Smoky fault truncates some folds in its foreland. Earlier workers have characterized the Pulaski fault in the same way. Coupled with the observation that the two faults are evidently folded at some locations (in particular, the Great Smoky fault is folded in the Newport area, S2C), this suggests the COCORP and Valley and Ridge thrust systems are partly synchronous.

The content of the Hot Springs window (S1D-1E), which consists of Precambrian to Cambrian rocks, seems to be part of the Pulaski thrust plate, as earlier workers have proposed. Coupled with COCORP seismic data discussed in the following chapter, this indicates that the Pulaski replaces the Great Smoky fault of further southwest as the structural boundary of the Blue Ridge, or COCORP fault.

In several parts of the Blue Ridge, at least three phases of major folding, possibly Taconic in age, can be identified, but it is doubtful that phases can be correlated regionally. The peak of metamorphism apparently occupies a different position in kinematic sequences in different areas. At Murphy (S8E), setting of isograds appears to predate a major folding event which, in turn, is no younger than the dominant foliation. Ninety km to the northeast, isograds are known to postdate the emplacement of the Greenbrier fault. Structure sections in the Greenbrier thrust sheet (fig. 11, page 64 and S3D-3E) strongly suggest that the Greenbrier postdates two phases of major folding, one syn- and the other postfoliation.

Generally, it is not possible to establish which, if any, of numerous postfoliation folds throughout the Blue Ridge, affect the

COCORP thrust at depth. Several folds can be eliminated from consideration, however, on the evidence of the structure sections. These include the Ravensford anticline (S3D-6F), the Robbinsville anticline (S7D-8D), and folds north of Calderwood window (S7B).

## CHAPTER II

### PALINSPASTIC RESTORATION OF OCOEE BASIN,

#### BASED ON COCORP GEOPHYSICAL DATA

In this study, assumptions about thrust architecture of the Blue Ridge province in Tennessee, and a structural interpretation of a COCORP seismic reflection profile, are used to reconstruct geometry of a late Precambrian to early Cambrian basin of deposition. In their restored position, rocks of the Ocoee Supergroup and Chilhowee Group can be related to reflectors on the COCORP profile, which may indicate their autochthonous equivalents.

#### Geologic Setting

The Blue Ridge and Valley and Ridge provinces of east Tennessee are part of a Paleozoic foreland fold and thrust belt on the northwest flank of the Appalachian orogenic system (fig. 1, page 5). The Blue Ridge in Tennessee is a mountainous physiographic province underlain mainly by metasandstones and metashales of Precambrian to Cambrian age. Bounding the Blue Ridge on the northwest is the Valley and Ridge province, a less rugged area underlain by Paleozoic strata, mostly carbonate rocks and shales.

In southeast Tennessee, the physiographic boundary is also a profound thrust fault, the Great Smoky fault. There is stratigraphic displacement such that the highest formation preserved in the Blue Ridge

(Rome Formation of lower Cambrian age) is the same as the lowest unit exposed in the Valley and Ridge. Windows in the thrust are within the Blue Ridge, up to 15 km southeast of the Valley and Ridge. On the basis of a seismic reflection profile (Cook et al., 1979), an event which probably represents a horizon in the Rome Formation can be shown to be displaced a minimum of 140 km on the Great Smoky fault.

In northeast Tennessee, the structural discontinuity crops out somewhere west of the physiographic boundary. At least one thrust (Holston Mountain fault) carries rocks spanning the two stratigraphic sections separated by the Great Smoky fault further south. A more northwesterly thrust (Pulaski fault) emerges entirely within Paleozoic rocks, but facies contrasts, between rocks on either side of the fault, suggest that it has very large displacement (Rodgers, 1953). A seismic reflection profile, from just northwest of the Holston Mountain fault trace to the Inner Piedmont in North Carolina, was recently made available by the U.S. Geological Survey (1980). Roeder (in prep.) interprets the profile to confirm Rodgers' (1953) suggestion that sub-Rome strata in the Mountain City window are in the Pulaski thrust sheet, and to show over 100 km of slip on the Pulaski fault. This would make the Pulaski fault, which crops out entirely within the Valley and Ridge physiographic province, the northwestern structural limit of the Blue Ridge.

The Great Smoky-Pulaski thrust is referred to in this study as the COCORP fault, because geophysical work beginning with that of the Continental Consortium for Reflection Profiling (COCORP; Cook et al.,

1979) has set it apart from the series of thrusts of smaller displacement on both sides of it.

### Comparison of Blue Ridge and Valley and Ridge Thrust Architecture

Northwest of (external to) the COCORP fault trace, no thrust that reaches the surface has a displacement of more than 40 km. However, the 7 to 10 thrusts comprising the sledrunner system of the Valley and Ridge root in a common decollement, which has a slip of 100 to 150 km beneath the easternmost Valley and Ridge (fig. 13).

A working hypothesis which will be used to compare thrust architecture of the two provinces is that the COCORP fault is analogous to the basal decollement in the Valley and Ridge subsurface, and that the Great Smoky, Miller Cove, and other tectonic units described in this report represent stumps of sledrunner thrust sheets.

The level of erosion permits Blue Ridge thrust architecture to be best understood in the most external tectonic units. Southwest of the French Broad River, these are the Great Smoky, Miller Cove, and Dunn Creek thrust plates. Windows and reentrants reveal that, at some location each of these tectonic units is directly in contact with overridden rocks of the Valley and Ridge. At Hot Springs (S1D-1E) the still more internal Brushy Mountain tectonic unit rests directly on rocks thought to be in the Pulaski plate (Roeder et al., 1978; Keller, 1980; and this study).



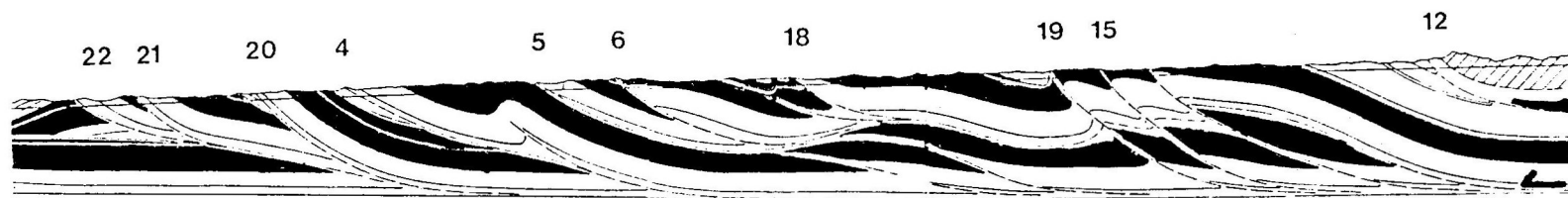


Figure 13. Basal decollement in Valley and Ridge province, in cross section (after Roeder et al., 1978).

Half-arrow at right edge of section represents position at which slip is approximately 120 km. At the surface, no thrust except the Great Smoky fault (no. 12 in this illustration) has a slip over 40 km. Section 6 of Roeder et al. (1978).

The conclusion is drawn that none of the tectonic units external to the Dunn Creek fault has a preserved cross sectional length over 13 km; and even the Dunn Creek plate is only 7 km long at Hot Springs.

Preserved cross sectional lengths of thrust plates in the adjacent Valley and Ridge range from 10 to 30 km (Roeder et al., 1978).

The cross sectional length actually in contact with the COCORP fault is also of interest. This is 1.5 to 12 km for the Miller Cove plate, which compares with 1 to 15 km of contact with the sole fault for plates in the Valley and Ridge.

In some locations, thrust faults occur within major tectonic units, subdividing them into smaller plates. North of Wear Cove (S5C), the Bogle Spring fault, within the Great Smoky plate, and the Happy Hollow fault, within the Miller Cove plate, are examples. The Bogle Spring subplate is in contact with the COCORP fault over 2 km; the Miller Cove for 2 km; the Happy Hollow for 3 km.

In successively more internal tectonic units of the Blue Ridge, stratigraphic level of the lowest rocks in a plate generally drops. In the sledrunner thrust plates of the Valley and Ridge, the level remains constant (Rome Formation).

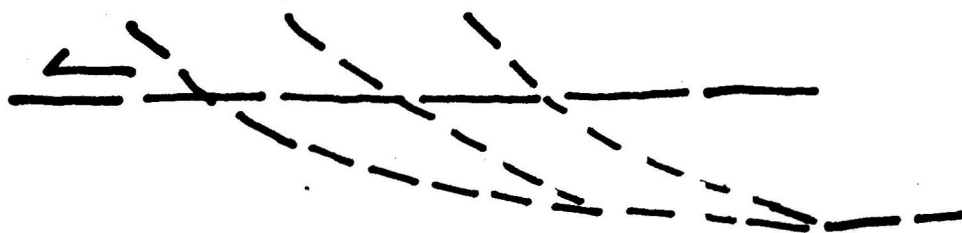
Finally, in units internal to the Miller Cove fault, one to three phases of macroscopic folding predate the thrusting, adding to structural complexity. Nevertheless, within each thrust plate, rocks lower in the section tend to crop out toward the internal edge. In other words, sheet dip regionally is to the northwest in units internal to the Miller Cove fault.

At least three possible models of thrusting, including sledrunner thrusting, could explain the preceding observations (fig. 14).

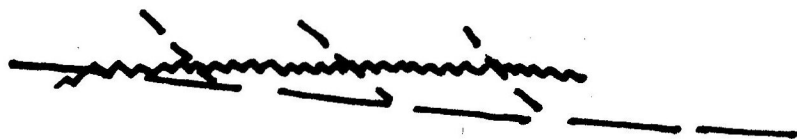
In the preassembled model (A), a stack of tabular units was assembled by thrusting, then crosscut and passively borne along on a subhorizontal COCORP fault.

The duplex model (B) proposes that the externalmost Blue Ridge is a giant duplex, the roof thrust of which is mostly eroded. Each tectonic unit is a horse plucked from a stepped major ramp, in which the COCORP fault climbed from Snowbird-Great Smoky rocks to the Rome Formation. King (1964, fig. 23, p. 122) illustrated this interpretation for the Great Smoky tectonic unit, implying a flattening updip for the eroded portion of the Miller Cove fault (fig. 15). In the giant duplex model suggested by fig. 15B, the Dunn Creek and Brushy Mountain fault would also flatten updip, and all faults would reunite updip with the eroded COCORP fault.

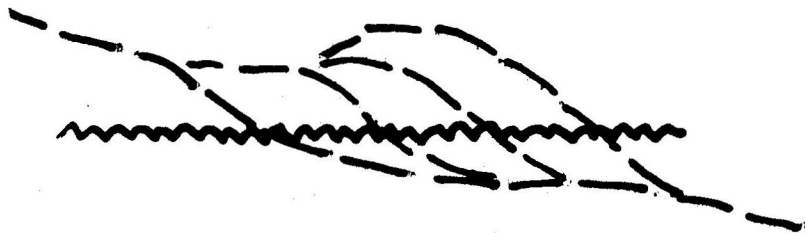
In the sledrunner model, imbricate thrust faults, bounding plates similar in size and shape to thrust plates of the present Valley and Ridge, overprinted previously deformed strata. These faults, including the Miller Cove, Dunn Creek, Happy Hollow, and Bogle Springs thrusts, each accumulated slip in the order of 10 km. Because there was a gentle northwestward sheet dip before thrusting, successively external thrusts involve rocks higher in the section. The 140 km+ slip between rocks of the Great Smoky plate and the Valley and Ridge could have been dispersed among similar sledrunner thrusts, involving Cambrian to Ordovician rocks, which were eroded when the later Valley and Ridge imbricate system began.



A. PRE-ASSEMBLED



B. DUPLEX



C. SLEDRUNNER

Figure 14. Three alternative models of Blue Ridge thrust architecture.

A: Great Smoky fault cuts down-section through preassembled stack. B: Plates external to Brushy Mountain fault are fault slices, with duplex relationship to Great Smoky thrusting. C: Tectonic units represent stumps of sledrunner-type thrusts.

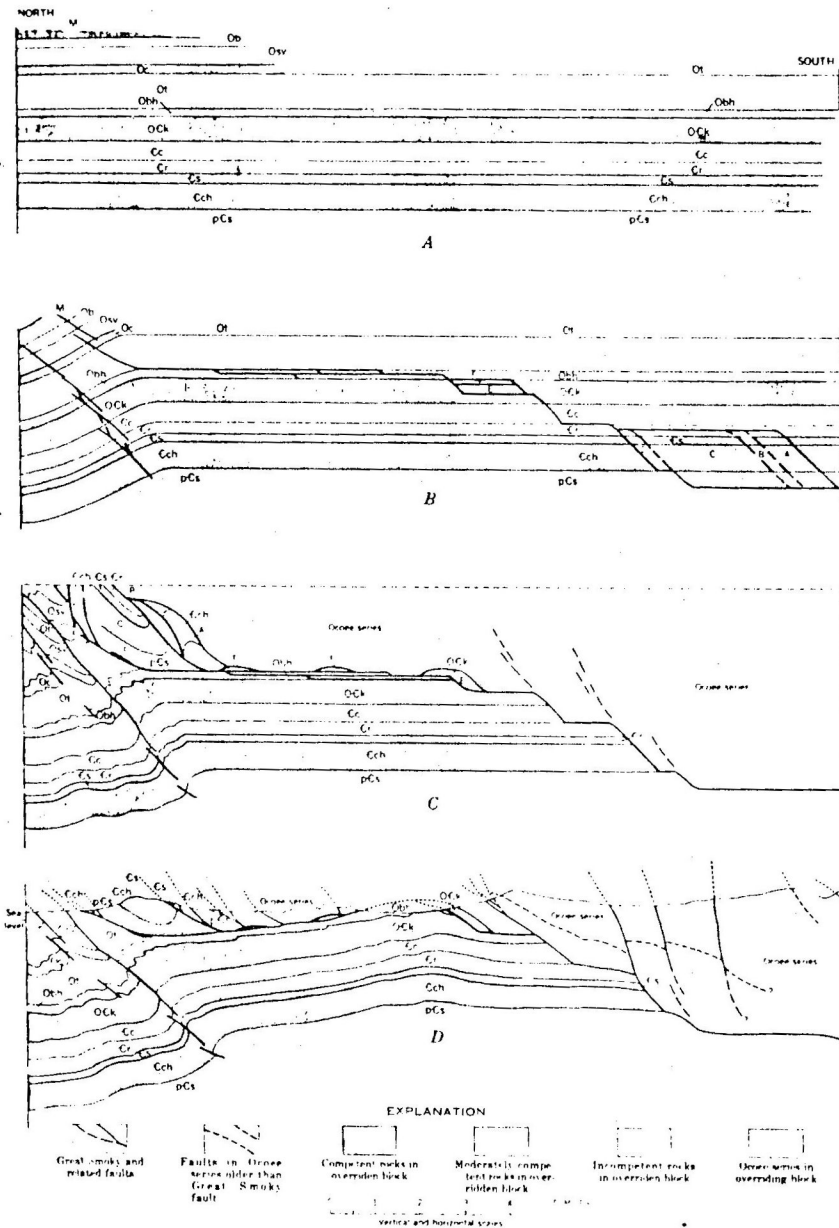


FIGURE 23.—Sequential sections showing inferred development of Great Smoky fault in relation to its overriding rocks. A, Before thrusting. B, Fractures in overriden rocks which determined course of fault. C, After thrusting. D, Present structure based on section J-J' of plate 9. Cch, Chidlowee group. Cs, Shady dolomite. Cr, Rome formation. Ock, Knox group. Obh, Blockhouse shale. Ot, Teillee formation. Oc, Chota formation. Osv, Saylor formation. Ob, Bays formation. M, Rocks of Mississippian age.

Figure 15. Duplex model, applied to footwall of Miller Cove fault (after King, 1964).

In the line of section 1, the Meadow Creek Mountain and Dunham Ridge faults would represent preserved thrusts of this type, while the Pulaski is the sole fault.

Evidently, it is not possible to prove any of the models. However, indications that the Miller Cove and Brushy Mountain faults (and possibly the Dunn Creek), like the Great Smoky, formed late in the Blue Ridge tectonic history, favor the latter two models over the preassembled model. It is mainly the scale of the system which makes the sledrunner model appear to be the more likely of the two remaining models for the system as a whole.

On a smaller scale, duplex structures seem to be associated with the Great Smoky fault, and probably include the Denton structure, and the cove windows, as discussed in Chapter I. These units will be referred to as "Intra-Great Smoky tectonic units."

In all three models, it is coincidence that the position where the upper block of the COCORP fault climbs out of the Precambrian is preserved so close to the edge of the thrust complex, determined by erosion. In regional perspective, this is true from about the Tennessee-Georgia state line to the French Broad River.

#### Stratigraphy of Lower Cambrian (Rome) to Middle Ordovician

Paleozoic facies variations between thrust units help to show that:

1. The COCORP fault in southeast Tennessee rides a considerable distance on a decollement in the middle Ordovician.



2. The Pulaski fault is the COCORP fault in northeast Tennessee; and that,

3. The Rome, Conasauga, Knox, and Tellico-Sevier clastic units are persistent for a large palinspastic distance southeast of their Valley and Ridge outcrop belts, although they do disappear far to the southeast, where Murphy belt strata may be equivalents of the first three units.

The following discussion of stratigraphy from Rome Formation upwards emphasizes variations between facies in different tectonic units. Locations referred to in text, and positions of thrust faults, are shown on a tectonic map (Plate III).

The Rome Formation is the lowest unit exposed in the Valley and Ridge of the study area, and is preserved above other strata in the Blue Ridge. The sequence from Rome through lower Ordovician contains fewer and finer clastics, and limestone in place of dolomite, toward more internal tectonic units. Thicknesses evidently vary little across the study area: the Rome Formation is about 500 m thick; the overlying Conasauga Group is about 800 m thick; and the Knox Group, capping the sequence, is about 800 m thick. The middle Ordovician section contains more and coarser clastics towards the southeast, and thickens abruptly southeastward in the eastern Valley and Ridge.

The lower Cambrian Rome Formation is exposed in the Dumplin Valley plate, in the Hot Springs window, and in the Great Smoky thrust plate. At Porterfield Gap (Samman, 1975), above the Dumplin Valley fault, the exposed interval consists of 50% dolomite, 40% sandstone, and 10% siltstone. At Hot Springs, the Rome is dominated by silty shales, with

substantial interbedded dolomite. Proportions of shale, sandstone, and dolomite in Rome exposures of the Great Smoky plate are uncertain due to poor exposure.

The Conasauga Group (Rodgers, 1953) is divided into a western phase consisting of shale with some limestone lenses and interbeds, a central phase divisible into six alternating shale and limestone units, and an eastern phase with a thick section of dolomite at the base. A still more easterly phase has limestone in place of dolomite at the base of the section. Boundaries between the first three phases strike more northerly than the thrust faults. The central-western boundary crosses the Dumplin Valley plate near Madisonville, Tennessee (S8A). The eastern-central boundary is overridden and displaced by the Pulaski thrust, so that all Conasauga outcropping in the Pulaski plate is in the eastern facies. The easternmost phase appears in Tennessee in the Hot Springs window (Oriol, 1950). Only the lowermost 300 m of section are preserved below the Great Smoky thrust.

The Knox Group in the Knoxville and Dumplin Valley plates is dominantly cherty dolostone, with subordinate limestone (Rodgers, 1953). Prolific sphalerite mineralization occurs in the Knoxville plate, but not in the Dumplin Valley plate. In the Guess Creek plate, the Knox Group is dolostone-dominated, but parts of the section contain substantially more limestone than does equivalent Knox to the northwest (Bumgarner, 1956).

The Knox Group of the Pulaski plate is more than half limestone, and is poorer in chert than Knox to the northwest (Rodgers, 1953). Knox

exposed in Tuckaleechee, Wear, and Cades Cove windows beneath the Great Smoky fault contains no more than 10% dolostone and is nearly chert-free (King, 1964; Neuman and Nelson, 1965).

The middle Ordovician section in the Knoxville plate consists of cobbly argillaceous limestone, sparry skeletal limestone, calcareous sandstone, and calcareous shale (Chickamauga Group), overlain by sandstone (Bays Formation). Much of the sequence is unique to the Saltville-Beaver Valley and Knoxville thrust sheets. The units fit into a facies pattern, interpreted by Walker (1977) as a former shelf edge dominated by an echinoderm-bryozoan reef structure. Although regionally, the shelf edge strikes parallel to the thrust architecture superimposed on it, an embayment east of Knoxville permits study of the shelf-to-slope transition (Benedict, 1977).

The middle Ordovician succession of the Dumplin Valley plate is over 2000 m thick or about 2.5 times the thickness of equivalent strata in the Knoxville plate. The basal 30-50 m (Lenoir Formation) consists of limestone. The remainder consists of calcareous shales, siltstones, and sandstones. Basinal facies, which formed in more than 300 m of water depth, make up the lower 1000 m of the clastic section, as opposed to shelf and minor slope facies exposed in the Knoxville plate. The basal 110 to 350 m of the clastic section is a graptolitic shale (Blockhouse Formation) interpreted as "deep basinal" facies, which may have formed in as much as 1000 m of water depth (Shanmugam and Walker, 1978).

The reconstruction of Roeder and Witherspoon (1978) provides for only 16 km of palinspastic separation between shallow water and deep

basinal facies thought to be of the same age (Benedict and Walker, 1978).

Middle Ordovician strata in the Pulaski plate are represented by clastics, including conglomeratic turbidites in the South Holston Dam area (Kellberg and Grant, 1956; Bowlin, 1979). The section has not been formally subdivided in this plate. Only the lowest 230 m of the middle Ordovician section is present below the Great Smoky fault at Tuckaleechee and Wear Coves. This portion of the section consists of 8 m of limestone overlain by shale.

#### Footwall Interactions of COCORP Fault

Interactions between the advancing Blue Ridge thrust complex and its footwall are documented by intra-Great Smoky fault tectonic units and by the structure of the Great Smoky fault at Hot Springs (S1D-1E). The former are slices roofed and floored by successive movement surfaces of the Great Smoky fault. Some of the slices were picked up where the main decollement changed to a higher stratigraphic level. Others may have been incorporated when folding in the foreland of the advancing thrust complex formed obstructions.

The Hot Springs and Denton structures preserve portions of a major ramp in the COCORP fault. The Hot Springs structure reveals that the fault climbs abruptly from basement through a thin Ocoee (late Precambrian) section and an anomalously thick section of Chilhowee (Eocambrian) and Shady (lowest Cambrian) to a position as high as the top of the Rome Formation. At this location (S1D-1E and Plate 4), the COCORP fault may

have climbed out of the basement near the zero edge of the Ocoee sediment wedge. A similar relationship exists in northeast Tennessee, but to the southwest the decollement travels a considerable distance within the Ocoee, as documented by sections 3-8.

Cambro-Ordovician Knox carbonates of the cove windows of the Great Smokies may be derived far southeast of their equivalents in the Valley and Ridge. This suggests that, in the lines of section passing through those windows, the COCORP thrust has travelled a considerable length on a decollement in or above the Knox. Hatcher (1971) believes carbonates present in the Brevard zone, 100 km southeast of the Blue Ridge front, to be Knox rocks plucked from a lower tectonic unit. If he is correct, then the top of the Knox can be thought of as the base of deformation for the COCORP thrust system over a thrusting distance of at least 100 km. Only when the Valley and Ridge system was initiated did the main sliding horizon drop to the level of the Rome Formation.

The proposed truncation, by the Great Smoky, Dunham Ridge, and Pulaski thrusts, of some folds in their footwalls (S1C, 2C, 5C) has important bearing on the timing of COCORP and Valley and Ridge thrusting. Folds indicate an active decollement beneath them, in the foreland of the advancing COCORP thrust system. As interpreted in the Tellico Plains area (S8A-8B), folds discordantly cut by the Great Smoky fault are a consequence of slip on a major unmapped fault, which branches from the basal decollement of the Valley and Ridge. In contrast, movement on the Saltville fault appears to postdate final emplacement of the COCORP system (S3B-5B). This evidence suggests that the Valley and Ridge thrust system began before the COCORP system stopped.



## Interpretation and Restoration of COCORP Seismic Reflection Data

A cross section based on the COCORP Georgia Line 1 profile (fig. 16) can be divided into three regions: an allochthonous portion, above the COCORP thrust; a lower, parautochthonous portion above the Valley and Ridge basal surface of slip; and an autochthonous portion. In palinspastic restorations, the parautochthon must be shifted southeastward at least 120 km, the minimum shortening in the Valley and Ridge due to sledrunner thrusting. Allochthonous material is shifted by this amount plus the amount of transport on the COCORP decollement.

The reflector at 2.8 seconds which is traced across the northwest 40 km of the Georgia Line 1 profile probably corresponds to the horizon, near the base of the lower Cambrian Rome Formation, which is the most prominent event in reflection profiles of the Valley and Ridge (Harris, 1976; Tegland, 1978; and COCORP Tennessee Line 1). This horizon is involved in Valley and Ridge thrusting, though it is so short a distance above the basal detachment horizon that it allows easy estimation of depth to base of deformation. On the Georgia Line 1 profile it belongs to, and probably is close to the base of, the parautochthon.

Subhorizontal reflections appear below 3 seconds, intermittently from vibration point no. (VPN) 750 to the southeast end of Georgia Line 1. The set of reflections thickens toward the southeast, ranging from 0 to 2.5 seconds thick. The subhorizontal events are interrupted around VPN's 1700 through 2300, by moderately southeast-dipping reflections. Because subhorizontal reflections appear to abut discordantly against dipping

Figure 16. Line drawing of COCORP Georgia Line 1, modified after Cook et al. (1980), and interpretation.

Numbers: selected vibration-point numbers. Heavy lines in interpretation: faults. Dot patterned area: parautochthon (below COCORP and above Valley and Ridge décollements). Shaded: autochthonous sediments.



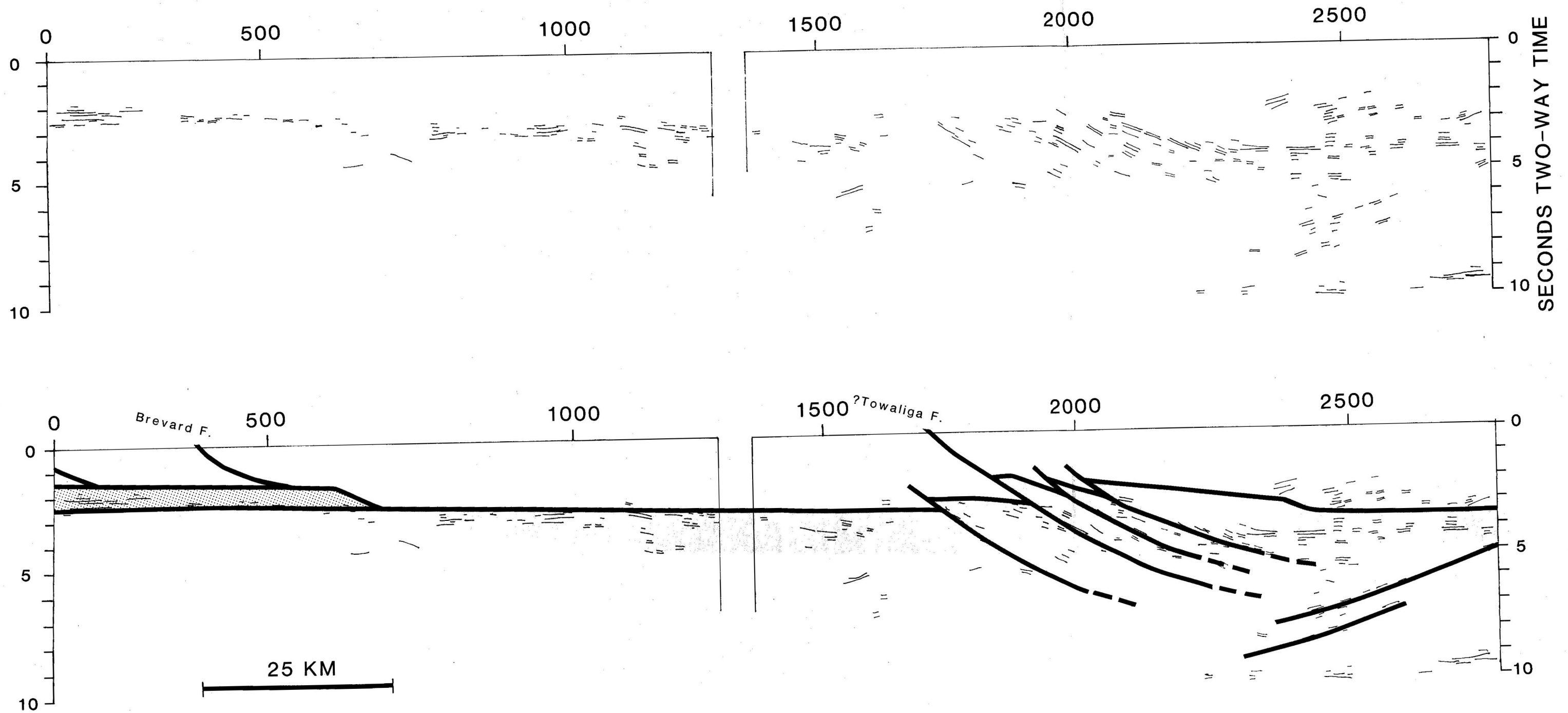


Figure 16.

reflections on both sides, the dipping reflectors may represent mylonite zones rather than sediments.

Some of the subhorizontal events may correspond to mylonites or other nonsedimentary features, but there is little reason to doubt that many of them, particularly the shallower events, are sedimentary (Cook et al., 1979).

In the Valley and Ridge belt of Tennessee, the top of Grenville basement, not far beneath the base of deformation which the Rome reflector marks, slopes smoothly southeastward at about 1.5 degrees. The probable Rome reflector in the northwesternmost 40 km of Georgia Line 1 is nearly on projection with the Valley and Ridge Rome reflector and basement top. On a time section, at least, the reflectors southeast of VPN 750 are below the projected basement top. Although the difference could be due to a velocity anomaly, the interpretation of Cook et al., that a normal fault downthrown to the southeast may be present, indicates that Cook et al. believe the difference in elevation is real. This apparent relief on the top of autochthonous basement is an important feature of the line, which has different significance depending on whether or not sediments are considered autochthonous.

If the presumed sediments southeast of VPN 750 are parautochthonous (above the Valley and Ridge decollement) as Cook et al. imply, then the following line of reasoning suggests that the Valley and Ridge decollement, below its projected level, rests in a depression in the basement top which was caused by subsidence (as opposed to tectonic "erosion"): Palinspastic restoration of the Valley and Ridge imbricate belt shows that material

originally near VPN 750 was transported to a position beneath, or northwest of, the frontal Blue Ridge of east Tennessee. The COCORP Tennessee line 1, southeast of Madisonville, shows a nearly planar Rome event, indicating that no basement-to-Rome ramp has been carried to this position by transport on the basal decollement. Therefore, the depression in the basement top cannot have been excavated by thrusting.

If sediments are parautochthonous, they should dip southeast near VPN 750, where the thrust sheet climbs out of the basement depression. If anything, dips are northwesterly (Cook et al., 1979). Thus, it is likely that the presumed sediments are autochthonous.

If the reflectors are autochthonous sediments, as is reasoned here, they are sub-Rome strata, because Rome Formation and higher rocks deposited on the site of the sediments have been transported northwestward. Because the series of reflectors thin in a northwesterly direction, until no sediments are observed below the Rome event northwest of VPN 750, VPN 750 is believed to be near the zero edge of the southeastward-thickening series of sediments, which include cratonward equivalents of the Shady, Chilhowee, Walden Creek, and perhaps Snowbird strata that crop out in the Blue Ridge.

Roughly coinciding, in the COCORP line of section, with the wedge of southeasterly thickening reflectors is a major regional gravity gradient, with a southeastward increase of 50 mgal. Thinned or transitional autochthonous crust might account both for the gravity gradient and the thickened sediments. Thinner than normal continental crust beneath the allochthon is also suggested by the tentative identification of the Moho

at about 30 km depth (10.5 sec) at the southeast end of Georgia Line 1 (Cook et al., 1979).

The writer's interpretation of the COCORP Georgia Line 1 (fig. 16), proposes that the wedge of reflectors southeast of VPN 750 corresponds to autochthonous sediments. The basal decollement is considered to have been planar originally, as far southeast as VPN 2400, where the decollement ramps up from a horizon 2 km lower, within the sub-Rome sediments. However, the base of COCORP and Valley and Ridge deformation was disrupted later on by more deeply-rooted thrusts, around vibration point no.'s 1700 through 2300. The COCORP and Valley and Ridge decollements separate where the Rome event is interpreted to terminate (approximately VPN 650). To keep displacement on the COCORP feature to a minimum (140 km), it is assumed that the COCORP fault cuts the Rome off at this point and has carried it to its present outcrop position at the Blue Ridge front. The original position of this ramp through the Rome was at least 120 km to the southeast, beyond the southeast end of Georgia Line 1, because the Valley and Ridge imbricate belt has to be restored.

#### Sub-Rome Stratigraphy of the Blue Ridge

Both within and between thrust plates in the Blue Ridge, there are considerable variations in thickness and facies of sub-Rome strata. The descriptions of strata below are mainly summarized from the published literature. Thicknesses are approximations, taken from the literature and from a series of cross sections by the writer (Plates I and II), in

turn based on published mapping. Relationships are summarized in an interpretive panel diagram, fig. 17.

### Hot Springs and Denton Tectonic Units

Rocks from basement (Precambrian, about 1 billion years old) through middle Ordovician occur in horizons between successive surfaces of movement of the Great Smoky thrust.

Crystalline basement within the Hot Springs window, described by Oriel (1950), is quartz-monzonitic in composition and has slight epidote alteration. Oriel describes unakite (a quartz monzonite in which plagioclase has been replaced by epidote) from the area, but mentions occurrences only in higher thrust sheets surrounding the window (above the Great Smoky fault).

The lowest 800 m of sediments in the Hot Springs window consist of arkose, feldspathic sandstone, and sandstone, with about 25% interbedded siltstone. These are overlain by 200 m of well-laminated siltstone and shale with interbeds of calcareous sandstone and sandy limestone. The strata were assigned to the Snowbird Formation by Oriel (1950), but the uppermost 200 m have affinities with, and are in the same stratigraphic position as rocks of the Miller Cove plate later designated as Walden Creek Group (King et al., 1958; Hamilton, 1961).

Above the foregoing clastics is the 180 m thick Sandsuck Formation, which consists of dark green to black silty shale or slate, with interbeds of calcareous sandstone low in the section, and conglomerate lentils at the top.

Figure 17. Interpretive fence diagram showing major sub-Rome stratigraphic units of the Blue Ridge, palinspastically restored.

Datum from which panels are suspended is base of Rome formation or its southeastward projection. Letters refer to locations of individual columnar sections, as follows: hs, Hot Springs window; gsn, footwall of Miller Cove fault close to French Broad River; gss, footwall of Miller Cove fault on Chilhowee Mountain; mcn, Miller Cove plate at French Broad River; mcs, Miller Cove plate in Richardson Cove area; dcn, Dunn Creek plate at French Broad River; dcc, Dunn Creek plate southeast of Richardson Cove; dcs, Dunn Creek plate near Cades Cove; bfg, Brushy Mountain plate in footwall of Greenbrier fault, along Pigeon River; sf, vicinity of Straight Fork "window" near northeast end of basement exposure in Ravensford anticline; hw, Hewitt.

Vertical scale is five times horizontal scale. Thick line portion of each columnar section is preserved and exposed; remainder of stratigraphy is speculative.

Random line pattern: Grenville-age basement. Black: Great Smoky group, plus "unclassified formations" (Cades, Rich Butt). Lower white: Snowbird group. Shading: Walden Creek group. Upper white: Chilhowee group plus Shady dolomite.

Wavy line: estimated position of COCORP fault break.

The panel at the lower left corner of the figure represents the sedimentary wedge interpreted to be preserved as autochthonous material on the COCORP profile (shaded material of fig. 17, p. 101), in its present-day position. The point where the basement-sediment contact reaches the top of the panel corresponds to vibration point no. 750 in fig. 17. The right end of the panel coincides with the right end of fig. 17. Sediments are not subdivided as in other panels, since stratigraphy is not known. The datum is the base of the Rome, projected from the position of the basal reflector in the northwestern end of the COCORP profile. Two additional panels are provided for spatial reference to the remainder of the diagram.



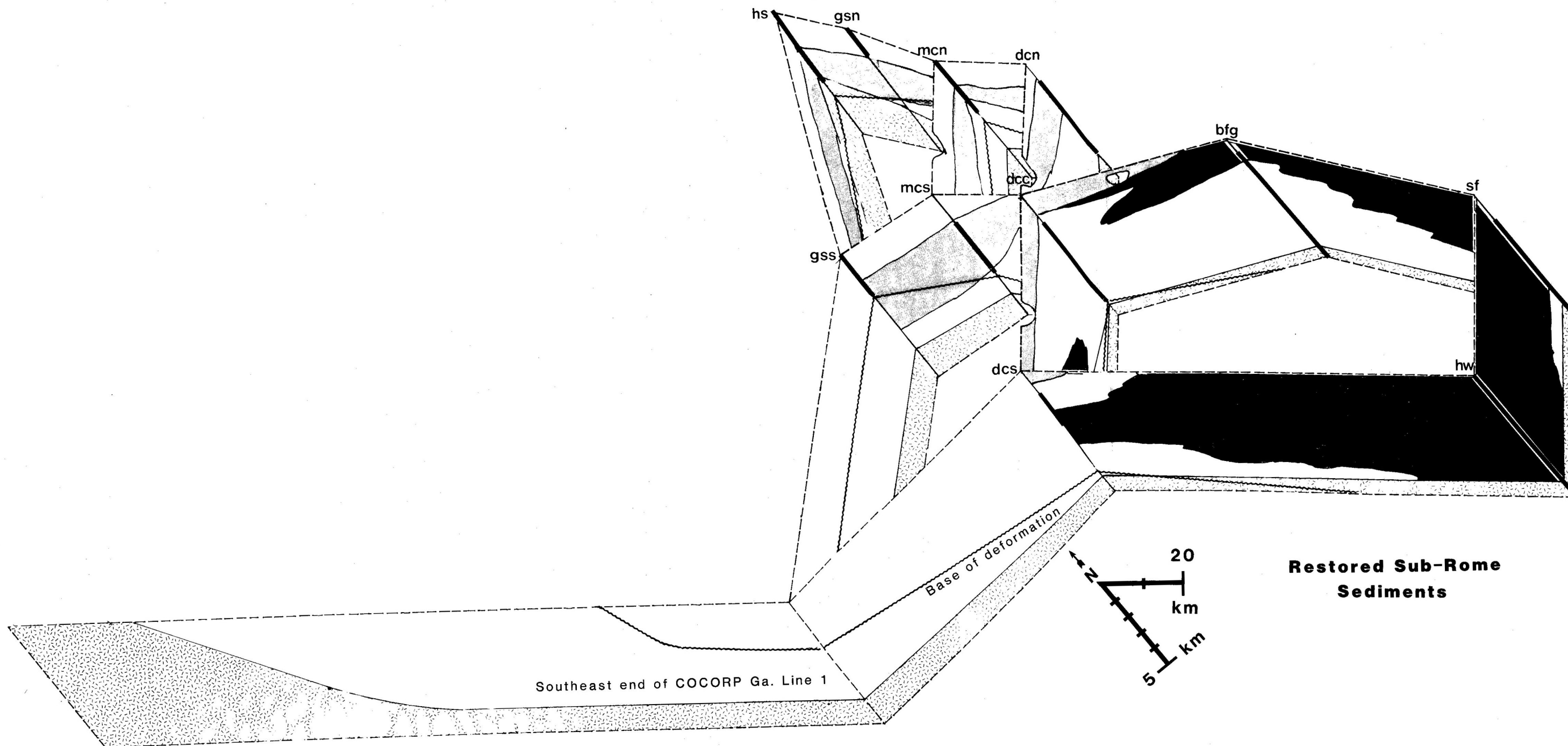


Figure 18.

The Chilhowee Group, possibly of lowermost Cambrian age, is 1700 m thick in the Hot Springs window. The lowest 300 m are incorporated into the Sandsuck by Keller (1980). The Chilhowee includes mainly quartzite and feldspathic sandstone, with about 500 m of shale and siltstone occurring near the middle of the section.

The Chilhowee Group is overlain by lower Cambrian Shady dolomite, which is up to 700 m thick in the Hot Springs window, and about 530 m thick at Denton. It is composed of dolomite, white to blue in color, with a small amount of interbedded limestone.

#### Great Smoky Plate (Footwall of Miller Cove Fault)

Up to 1000 m of Sandsuck Formation are preserved above the Great Smoky fault, along English Mountain and Chilhowee Mountain. Like Sandsuck exposed in the Hot Springs window, the formation consists of silty shale, with thick beds of sandstone and conglomerate near the top of the section. However, fine-grained material is lighter in color (light gray or greenish gray) and commonly uncleaved.

The Chilhowee Group is 1330 m thick on English Mountain and 1000 m thick on Chilhowee Mountain, or much thinner than at Hot Springs or Denton.

The lower Cambrian Shady Dolostone is 350 m thick on the Chilhowee and English Mountain blocks, in contrast to its 600 m thickness at Denton and Hot Springs. As at Denton and Hot Springs, the rocks are gray dolomite; dolomitic shale interbeds are common in the upper third of the section (Neuman and Nelson, 1965).

### Miller Cove Plate

The exposed rocks of the Miller Cove plate are all within the late Precambrian Walden Creek Group, except in the area between the Pigeon and French Broad Rivers. In that area both higher and lower strata are present. Thickness estimates in the Pigeon-French Broad area can now be refined on the basis of detailed mapping by Keller (1980).

At least 450 m of late Precambrian Snowbird Group are present beneath the Walden Creek Group in the Miller Cove plate of the Pigeon-French Broad area. The section consists of 200 exposed m of Roaring Fork Formation, dominated by fine-grained arkosic sandstones, and 250 m of Pigeon Formation, dominated by blue- or green-gray siltstones with lenticular sand laminations.

In the same area, the Walden Creek Group is about 350 m thick, but in the Richardson Cove area, it has a minimum thickness of 3050 m (Hamilton, 1961). The clastic strata that make up the Walden Creek Group are distinguished by their carbonate (often ankerite) cement; by conglomerates with highly spherical, rounded quartz pebbles and angular shale clasts; by polymict conglomerates with clasts up to 1 m in diameter, consisting of sandstone, vein quartz, and limestone; and by limestone interbedded with shale at the top of the Wilhite Formation.

In the Pigeon-French Broad area, where a complete but thin section is exposed, only two units, the Wilhite and the Sandsuck, are recognized (Keller, 1980). Four units are identified at Richardson Cove (Hamilton, 1961), the Licklog, Sheilds, Wilhite, and Sandsuck formations.

Only the upper 100 m of the Licklog Formation, lowest unit of the Walden Creek, are exposed in Richardson Cove. The Licklog consists of

blue-gray lenticular-laminated siltstone, quite similar to the Pigeon Formation which underlies the Walden Creek. Overlying the Licklog is the 700 m thick Shields Formation, which is dominated by conglomerates and sandstones, but which contains a member of dark, lenticular-laminated siltstone and shale. The 1100 m thick Wilhite Formation, above the Shields, is dominated by similar siltstone and shale, with members of conglomerate and sandstone similar to the bulk of the Shields. The Yellow Breeches member at the top of the Wilhite is a distinctive subunit, consisting of dark shale with limestone or sandy limestone interbeds.

Preserved at Richardson Cove, are 1150 m of Sandsuck Formation. The Sandsuck consists of interlaminated siltstone and fine grained sandstone, with a middle 390 m thick member of coarse sandstone and quartz conglomerate.

In the Pigeon-French Broad area, the Sandsuck is overlain by a 1700 m thick section of Chilhowee Group.

Rocks typical of Wilhite and Shields formations occupy the Miller Cove plate southwest of Richardson Cove. The distinctive conglomerate and limestone units are recognized at least as far south as the Tennessee-Georgia state line (Sutton, 1971), and possibly as far south as Cartersville, Georgia (Costello and McConnell, 1980). Confidence of assigning these strata to a particular level in the Wilhite-Shields section deteriorates with distance from Richardson Cove, because of minor faults within the Miller Cove plate, and because many of the rock types are common to both Wilhite and Shields.

Except for a belt of Licklog strata north of Wear Cove, the Licklog and Sandsuck formations are not recognized in the Miller Cove plate southwest of Richardson Cove.

### Dunn Creek Plate

The Dunn Creek plate contains a sequence of late Precambrian strata, more than 6 km thick, consisting of pelites and fine to medium grained sandstones of the Snowbird Group, and coarser facies equivalents of the Snowbird. The top of this sequence is preserved in the Dunn Creek plate, in the Pigeon-French Broad River area. There the Snowbird is overlain by more than 2 km of the Walden Creek Group. This section of Walden Creek rocks is over 5 times as thick as the Walden Creek Group in the Miller Cove plate immediately to the northwest, based on structural data and outcrop widths mapped by Keller (1980).

In its type area, the Snowbird Group contains four formations, identified from the base upward as the Wading Branch, Longarm, Roaring Fork, and Pigeon formations. The type area is along the Pigeon River, straddling the Tennessee-North Carolina state line, and was formerly thought to lie in the Dunn Creek plate (Hadley and Goldsmith, 1963). Detailed mapping by Keller (1980), on the east side of the Pigeon River, shows that a thrust fault of large displacement (Brushy Mountain fault) separates the type area of the Snowbird from Snowbird rocks of the Dunn Creek plate.

Only the upper two formations of the Snowbird are recognized in the Dunn Creek plate as redefined. The Roaring Fork Formation, at least 1 km thick in the Dunn Creek plate, consists of medium-bedded,

fine-to-medium grained feldspathic sandstone, with some finer-grained interbeds. The Pigeon Siltstone, of which 5 km are preserved, is dominated by greenish-gray lenticular-laminated siltstone. Material in the lenses ranges from siltstone to fine sandstone, and often has ankerite carbonate in the matrix. The material surrounding the lenses is more chloritic, and ranges from clay to silt. Fine grained material in the Pigeon is free of organic carbon in most areas, in contrast to fine grained material typical of the Walden Creek and Great Smoky groups. Medium interbeds of fine to medium-grained feldspathic sandstone, also occur in the Pigeon.

Between Gatlinburg and Cades Cove, rocks resembling the Pigeon Siltstone, but finer-grained on the average, occur in the Dunn Creek plate and are assigned to the Metcalf Phyllite. The main foliation, and tectonic fabrics overprinting it, commonly have obliterated sedimentary structures in the Metcalf, but lenticular-laminate bedding similar to that in the Pigeon is observed in some places.

Southwest of the Little Tennessee River, strata similar to the Metcalf and to the Pigeon appear again in the Dunn Creek plate. These strata were assigned to the Walden Creek Group by Hurst and Schlee (1962) and Hardeman et al. (1966), but to the Snowbird Group by Merschat and Wiener (1973). The rocks have features in common with typical Walden Creek Group, including carbonate conglomerates and considerable ankerite content, but appear to lack the dark-colored pelites and the characteristic bedded black limestones and round pebble conglomerates. [Rocks immediately to the northwest, in the footwall of the Dunn Creek



(Sylco Creek) fault, bear all these earmarks and undoubtedly belong to the Walden Creek Group (Merschatt and Wiener, 1973; Wiener, pers. comm., 1979)].

That the Walden Creek overlies the Snowbird can be demonstrated in the Pigeon-French Broad area (Hadley and Nelson, 1971; Keller, 1980). Possibly the fine-grained rocks in the Dunn Creek plate in southeast Tennessee are near the top of the Snowbird section, and therefore have a transitional character.

A controversial aspect of stratigraphy within the Dunn Creek plate is the relationship to the Snowbird of massive-bedded coarse sandstones and interbedded dark sulfidic pelites, which occur in the midst and to the south of the Snowbird belt of outcrop. The sandstone and dark pelites have been assigned to the Cades, Thunderhead, and Elkmont formations by King (1964), and similar rocks were informally called "sandstones of Webb Mountain" by Hamilton (1961). In the eastern Great Smoky mountains, between Gatlinburg and the Pigeon River, the contact between the Snowbird Group and many of these rocks is a well-recognized thrust (Greenbrier fault; Hadley and Goldsmith, 1963). However, the contact becomes more irregular and the relationship controversial from Gatlinburg westward. In Cades Cove, 32 km west of Gatlinburg, good exposures with reliable facing criteria show that the coarse sandstone facies stratigraphically underlies the Metcalf Phyllite in some locations, and overlies it in others (Neuman and Nelson, 1965). Between Gatlinburg and Cades Cove, the contact is probably a fault at some outcrops, demonstrated by mylonite fabric (guidebook stop 4b). In

other outcrops of the contact in this area, including some mapped by King (1964) as faulted, there is abundant evidence of a stratigraphic relationship.

In such outcrops, Snowbird pelites often become gradually darker and more sulfidic as the contact is approached. Pelites interbedded with the massive sandstones, typically dark and sulfidic, have obvious lenticular-laminated structure near to the contact. These relationships are especially evident along the north slope of Cove Mountain, although mapping by King presents a tectonically more complicated picture. Specifically, in the Raven Den area (guidebook stop 6), refaulted faults are postulated by King (1964) to account for 50 m thick, bedding-parallel bodies of massive sandstone within the Metcalf Phyllite. The fine-grained rocks outcropping between the supposed fault slices range continuously from greenish-gray to dark gray lenticular-laminated siltstones and fine sandstones. They are continuous into the main body of the Metcalf Phyllite. A fault relationship between the coarse sandstones and the phyllite at this location appears to be ruled out.

On the east side of Cove Mountain, rocks mapped by King (1964) as Pigeon and Roaring Fork formations, include a 1200 m thick section of sulfidic dark siltstone, massive bedded coarse sandstones, and sequences in which these lithologies are interbedded (guidebook stops 11-12). The strike and dip of these rocks and of a group of very similar rocks along strike to the west, are the same (fig. 8, page 53), although the latter group was mapped as Thunderhead and Elkmont formations, and the two groups of rocks are supposed to be separated by the Greenbrier fault

and later thrusts (King, 1964). The interpretation proposed here is that the two groups of strata are in fact stratigraphically continuous. The change, east of Cove Mountain, from massive sandstones and dark pelites to typical Pigeon Formation is gradual, not abrupt, and is interpreted as a lateral facies change.

Regionally, the following interpretation is proposed: The Snowbird Group in the Dunn Creek plate, which is at least 6000 m thick, is equivalent to 1100 m of Snowbird, plus a portion of the 6500 m thick Great Smoky Group, which appear above the Greenbrier fault. The massive, coarse sandstones in the Dunn Creek plate represent tongues and lentils of the Great Smoky group, at the transition zone between the two facies. This includes rocks mapped by King (1964), Hamilton (1961), and Neuman and Nelson (1965) as Thunderhead, Elkmont, and Cades formations, and "sandstone of Webb Mountain." If these rocks and much of the Snowbird are intertonguing equivalents as here is suggested, there is no problem in the observation that Snowbird-like rocks overlie massive, coarse sandstone along Tellico River and further south (Poppelreiter, 1980; Hale, 1974; Hurst and Schlee, 1962).

#### Brushy Mountain Plate

The Brushy Mountain plate contains two tectonic units brought together, probably in early Paleozoic time, by movement on the Greenbrier fault. The footwall and hanging wall of the Greenbrier fault are considered separately.

Footwall of Greenbrier fault. At least 6 km of sediments of late Precambrian age are preserved beneath the Greenbrier fault. The sediments

overlie basement which is probably one billion years old, and consist of five formations, the lowest four of which are assigned to the Snowbird Group.

The lowest unit, the Wading Branch Formation, is a 400 m assemblage of massive bedded, poorly sorted sandstones with graded bedding, interbedded with dark fine-grained rocks. The Longarm Quartzite, overlying the Wading Branch, is a 2700 m thick sequence of cross-bedded arkose and feldspathic sandstone. The Roaring Fork Sandstone, 1300 m thick in the footwall of the Greenbrier fault, is similar to Roaring Fork in the Dunn Creek plate. Overlying the Roaring Fork, the Pigeon Formation is only 1250 m thick, in contrast to its thickness of at least 5000 m in the adjacent portion of the Dunn Creek plate. It has a larger proportion of medium grained sandstone interbeds than is present in the more external plate, and it intertongues southward with the underlying Roaring Fork Formation (Hadley and Goldsmith, 1963; Keller, 1980). The Rich Butt Formation, overlying the Pigeon, contains well-laminated coarse sandstone which is ankeritic in some places. It is coarser than, but similar to, Walden Creek strata of the Dunn Creek plate in the Pigeon-French Broad area (Keller, pers. comm., 1978), which are in a similar stratigraphic position.

Hanging wall of Greenbrier fault. The Snowbird Group, overlying basement in portions of the upper block of the Greenbrier fault, reaches a maximum thickness of 1100 m, contrasting with a thickness of 5600 m in the footwall of the Greenbrier. The Pigeon and Rich Butt formations are not recognized in the hanging wall of the Greenbrier, but Wading

Branch, Longarm, and Roaring Fork formations are each intermittently present between basement and the base of the Great Smoky Group. Southwest of the Tuckasegee River, and southeast of Maggie, no Snowbird strata are recognized.

The Great Smoky Group is roughly 6.5 km thick, based on structure sections in the Bryson City area (S6E). It consists of massively bedded, poorly sorted coarse sandstones with graded bedding, and dark, typically sulfidic, pelitic rocks. In any particular area, the Great Smoky Group section contains at least one unit, up to 1.5 km thick, dominated by pelitic rocks. However, the units seem to occur at various levels in the section, and none of these units may be continuous throughout the area of study.

Overlying the Great Smoky Group is a sequence of dominantly clastic metasediments, informally designated the Murphy Belt group (Kish et al., 1975). The group consists mainly of light-gray to dark metapelitic rocks, but two distinctive quartzite units and a carbonate unit (Murphy Marble) permit a relatively consistent stratigraphy to be mapped from near Cartersville, Georgia, to the area of Bryson City. Reported thicknesses of units in the Murphy Belt group vary greatly from area to area. Based on contacts and bed attitudes of Forrest (1975), 2.5 km of strata are between the top of the Great Smoky Group and the Murphy marble in the Murphy area. The remaining preserved section is 2.2 km thick. However, in the Mineral Bluff area of north Georgia, only 1.5 km of Murphy Belt strata are present below the marble, which is near the top of the preserved section (Hurst, 1955). The discrepancy may result from



greater shortening normal to bedding in the Mineral Bluff area, in which the strata crop out in the core of an isoclinal syncline.

The huge (10 km+) thickness of strata in the upper block of the Greenbrier fault suggests the strata may have accumulated on thinned or transitional crust.

McLaughlin and Hathaway (1975) reported a brachiopod from the Murphy Marble near Hewitt, which indicates the marble is Paleozoic, possibly as young as middle Ordovician. Kish et al. (1975) state that an unconformity may exist within the Murphy Belt section to account for the absence of the Chilhowee, Shady, Rome, Conasauga, or Knox units of more external thrust plates. Using a similar argument, Wiener (1976) postulated a pre-middle Ordovician unconformity at the base of the Great Smoky Group, correlating the Great Smoky sequence with middle Ordovician clastics of the Valley and Ridge. The interpretation of the writer is that palinspastic distance between the Murphy Belt strata and the Chilhowee-Shady-Rome rocks of the Miller Cove plate is on the order of a hundred or more kilometers, more than sufficient distance for major facies changes. In this view, the Murphy Belt group and possibly part of the underlying Great Smoky Group are lower Paleozoic in age, representing shelf-edge equivalents of rocks of the Valley and Ridge.

#### Palinspastic Restoration

Figure 17, page 101, is a reconstruction of the sub-Rome sedimentary wedge of the Blue Ridge in its proposed palinspastic relation to autochthonous material of the COCORP profile. The palinspastic base,



on which the panel diagram has been erected, is based on displacements calculated from the COCORP Georgia Line 1, as interpreted in fig. 16, page 95; on cross section 8 of Roeder et al. (1978) and cross section 8 of Plates I and II; and on the sledrunner thrust interpretation of the frontal Blue Ridge (fig. 14C, page 86).

Vertically, the panels are suspended from the base of the lower Cambrian Rome Formation, actual or projected. In the southernmost columnar section (at Hewitt), although the preserved section extends into the Ordovician, the Rome Formation is not present. If the Murphy Marble is arbitrarily correlated with part of the upper Knox Group and the interval correlating with Rome through Knox at Hewitt is no thicker than the corresponding interval in the Valley and Ridge province, the base of the Rome is projected into a horizon near the top of the Great Smoky Group (Dean Formation). This leaves about 8 km of section between the basement and the projected Rome horizon at Hewitt.

At the northernmost columnar section (at Hot Springs), the basement is about 2500 m below the base of the Rome Formation. An assumption in fig. 17, page 101, is that the basement is no deeper between the two locations than it is at Hewitt. The resulting correlations differ from those set forth by King et al. (1958), and are based on evidence, discussed above, that the Great Smoky and Snowbird Groups are partly facies equivalent. Alternate constructions that would agree with the proposition by King et al. (1958), that the Great Smoky is everywhere higher than the Snowbird, could also have been made. For example, the basement could be presumed deepest at locations external to the Greenbrier

fault, or the Murphy Marble could be assigned a lower Cambrian age, dropping the base of the Hewitt section by 2-3 km relative to the base-of-Rome datum.

The panel diagram also suggests that the strike of lithofacies boundaries was originally about 80 degrees east of north. In contrast, thrust faults strike about 60 degrees east of north. As a result, rocks of the Blue Ridge in northeast Tennessee are part of thinner, more cratonward sections than those of southeast Tennessee.

The panel in the lower left corner of fig. 17, page 101, represents the autochthonous sub-Rome sediments of the COCORP Georgia Line 1, as interpreted in fig. 16, page 95. The sedimentary rocks may be Chilhowee-Shady, Walden Creek, and possibly Snowbird Group rocks, based on projecting stratigraphy from other panels.

In fig. 17, the estimated position of the COCORP fault or base of deformation is shown as a wavy line. The ramp out of sub-Rome strata near the southeast end of the interpreted COCORP Georgia Line 1 is on (55 degrees east of north) strike with the similar ramp at Hot Springs. The presence of basement in allochthonous rocks of the Hot Springs window results from the fault cutting at a lower angle than the slope on the basement top.

At best, fig. 17 shows general outlines of the sub-Rome sediment wedge. In detail, the basement might descend southward with block-faulted geometry. In rough outline, the thickening of the wedge southward is consistent with a crust which is more oceanic in character toward the south. That the basement in the next major thrust plate southeast of

the study area (Hayesville plate) contains many mafic and ultramafic inclusions may be another indication of the same transition.

### Conclusions

COCORP seismic reflection data is interpreted to establish a minimum slip of 140 km for the COCORP fault in southeast Tennessee. A palinspastic restoration of the Blue Ridge is attempted, based on the idea that actual slip of the COCORP fault is close to this minimum figure, and the hypothesis that the frontal Blue Ridge is the eroded stump of a sledrunner thrust belt.

The palinspastic model forms a base for a fence diagram reconstruction of Blue Ridge sedimentary units. Correlations are influenced by observations of Neuman and Nelson (1965) and the writer that strata assigned to the Snowbird Group interfinger extensively with rocks assigned to, or strongly similar to, the Great Smoky Group. Correlations are further based on a lower Ordovician or younger age of the Murphy marble and the assumption that the floor of the basin descends monotonically southeastward.

The fence diagram represents the Chilhowee, Walden Creek, Snowbird, and Great Smoky groups as partly facies-equivalent strata.

Strike of facies boundaries, in palinspastic restoration, is east-west, or as much as 30 degrees more easterly than strike of faults of the COCORP thrust system. In its restored position, the sedimentary wedge can be tied to a proposed wedge of autochthonous sediments beneath east-central Georgia, suggested by COCORP seismic reflection data.

## LIST OF REFERENCES

## LIST OF REFERENCES

- Armstrong, R. L., 1966, K-Ar dating of plutonic and volcanic rocks in orogenic belts, in Schaeffer, O. A., and Zahringer, J., eds., Potassium-argon dating: New York: Springer-Verlag, p. 117-133.
- Bally, A. W., Gordy, P. L., and Stewart, G. A., 1966, Structure, seismic data, and orogenic evolution of southern Canadian Rocky Mountains: Bull. Canadian Petroleum Geology, v. 14, p. 337-381.
- Benedict, George, 1977, Lenoir, Holston, and Ottosee formations: shallow shelf lagoon, deeper shelf, and shelf marginal environments in Ruppel, S. C., and Walker, K. R., The ecostratigraphy of the middle Ordovician of the southern Appalachians (Kentucky, Tennessee, and Virginia): a field excursion: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci., Studies in Geology 1, p. 52-58.
- Bridge, Josiah, 1955, Disconformity between lower and middle Ordovician series at Douglas Lake, Tennessee: Geol. Soc. America Bull., v. 66, p. 725-730.
- \_\_\_\_\_, and Hatcher, R. D., 1973, Geologic map of the New Market quadrangle: Tennessee Dept. of Conservation, Div. of Geology, Geologic Map GM 155-SE, scale 1:24,000.
- Bowlin, B. K., ms 1979, Descriptive, interpretive, and quantitative study of the coarse clastics of the middle Ordovician Tellico formation in the vicinity of South Holston Dam, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 256 p.
- Bryant, Bruce, and Reed, J. C., Jr., 1970, Geology of the Grandfather Mountain window and vicinity, North Carolina and Tennessee: U.S. Geol. Survey, Prof. Paper 615, 190 p.
- Bumgarner, J. B., ms 1956, Stratigraphy and structure of the Knox dolomite in the Fair Garden area, Sevier and Jefferson Counties, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 46 p.
- Byerly, D. W., ms 1966, Structural geology along a segment of the Pulaski fault, Greene County, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 94 p.
- Carpenter, R. H., 1970, Metamorphic history of the Blue Ridge province of Tennessee and North Carolina: Geol. Soc. America Bull., v. 81, p. 749-761.

- Cattermole, J. M., 1955, Geology of the Shooks Gap quadrangle, Tennessee: U.S. Geol. Survey Geol. Quad. Map GQ-76, scale 1:24,000.
- \_\_\_\_\_, 1962, Geology of the Maryville quadrangle, Tennessee: U.S. Geol. Survey Geol. Quad. Map GQ-163, scale 1:24,000.
- Clark, H. B., Costain, J. K., and Glover, Lynn, III, 1978, Structural and seismic reflection studies of the Brevard ductile deformation zone near Rosman, North Carolina: *Am. Jour. Sci.*, v. 278, p. 419-441.
- Cook, F. A., Albaugh, D. S., Brown, L. D., Kaufman, S., Oliver, J. E., and Hatcher, R. D., 1979, Thin-skinned tectonics in the crystalline southern Appalachians; COCORP seismic reflection profiling of the Blue Ridge and Piedmont: *Geology*, v. 7, p. 563-567.
- Costello, J. O., and McConnell, K. I., 1980, Stratigraphy of the southwestern Blue Ridge and northernmost Piedmont of Georgia (abs.): *Geol. Soc. America Abs. with Programs*, v. 12, no. 4, p. 175.
- Dahlstrom, C. D. A., 1969, Balanced cross sections: *Canadian Jour. Earth Sciences*, v. 6, p. 743-757.
- \_\_\_\_\_, 1970, Structural geology in the eastern margin of the Canadian Rocky Mountains: *Bull. Canadian Petroleum Geology*, v. 18, p. 332-406.
- Dallmeyer, R. D., Courtney, P. S., and Wooten, R. M., 1978, Stratigraphy, structure and metamorphism east of the Murphy syncline, Georgia-North Carolina: *Georgia Geol. Soc., Guidebook 17*, 74 p.
- Elliott, David, 1976, The motion of thrust sheets: *Jour. Geophys. Research*, v. 81, p. 919-963.
- \_\_\_\_\_, and Johnson, M. R. W., 1980, Structural evolution in the northern part of the Moine thrust belt, NW Scotland: *Trans. Royal Soc. London*, v. 71, p. 69-96.
- Epstein, A. G., Epstein, J. B., and Harris, L. D., 1977, Conodont color alteration — an index to organic metamorphism: *U.S. Geol. Survey Prof. Paper 995*, 27 p.
- Espenshade, G. H., 1963, Geology of some copper deposits in North Carolina, Virginia, and Alabama: *U.S. Geol. Survey Bull.* 1142-I, 50 p.
- Ferguson, H. W., and Jewell, W. B., 1951, Geology and barite deposits of the Del Rio district, Cocke County, Tennessee: *Tennessee Dept. of Conservation, Div. of Geology, Bull.* 57, 235 p.



- Forrest, J. T., ms 1975, Geologic evolution of a portion of the Murphy Marble belt in southwestern North Carolina: Rice Univ., Houston, Texas, Ph.D. dissert., 76 p.
- Greene, R. C., ms 1959, Geology of English Mountain and vicinity, Cocke, Jefferson, and Sevier Counties, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 46 p.
- Hadley, J. B., and Goldsmith, Richard, 1963, Geology of the eastern Great Smoky Mountains, North Carolina and Tennessee: U.S. Geol. Survey Prof. Paper 349-B, 118 p.
- \_\_\_\_\_, and Nelson, A. E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U.S. Geol. Survey Map I-654, scale 1:250,000.
- Hale, Robin C., 1974, Gold deposits of the Coker Creek district, Monroe County, Tennessee: Tennessee Dept. of Conservation, Div. of Geology, Bull. 72, 93 p.
- Hamilton, W. B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U.S. Geol. Survey Prof. Paper 349-A, 55 p.
- Hardeman, W. D., Miller, R. A., and Swingle, G. D., 1966, Geologic map of Tennessee: Tennessee Dept. of Conservation, Div. of Geology, scale 1:250,000.
- Harris, L. D., 1976, Thin-skinned tectonics and potential hydrocarbon traps — illustrated by a seismic profile in the Valley and Ridge province of Tennessee: U.S. Geol. Survey Jour. Research, v. 4, no. 5, p. 379-386.
- \_\_\_\_\_, and Milici, R. C., 1977, Characteristics of thin-skinned style of deformation in the southern Appalachians, and potential hydrocarbon traps: U.S. Geol. Survey Prof. Paper 1018, 40 p.
- Hartley, M. E., III, 1973, Ultramafic and related rocks in the vicinity of Lake Chatuge: Georgia Geol. Survey Bull. 85, 61 p.
- Hatcher, R. D., Jr., ms 1965, Structure of northern portion of the Dumlplin Valley fault zone in east Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Ph.D. dissert., 130 p.
- \_\_\_\_\_, 1971, Stratigraphic, petrologic, and structural evidence favoring a thrust solution to the Brevard problem: Am. Jour. Sci., v. 270, p. 177-202.
- \_\_\_\_\_, 1978, Tectonics of the western Piedmont and Blue Ridge, southern Appalachians: review and speculation: Am. Jour. Sci., v. 278, p. 276-304.

- \_\_\_\_\_, and Bridge, 1973, Geologic map of the Jefferson City quadrangle: Tennessee Dept. of Conservation, Div. of Geology, Geologic Map GM 163-SW, scale 1:24,000.
- \_\_\_\_\_, and Butler, J. R., 1979, Guidebook for southern Appalachian field trip in the Carolinas, Tennessee, and Georgia: International Geologic Correlation Program, The Caledonides in the U.S.A.: Field Conferences and Symposium of the Caledonide Orogen Project, 117 p.
- Holcombe, Rodney J., ms 1973, Mesoscopic and microscopic analysis of deformation near Ducktown, Tennessee: Stanford Univ., Palo Alto, Calif., Ph.D. dissert., 225 p.
- Hurst, V. J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Geol. Survey, Bull. 63, 137 p.
- \_\_\_\_\_, and Schlee, J. S., 1962, Ocoee metasediments, north central Georgia-southeast Tennessee: Geol. Soc. America, Southeastern Section, Guidebook 3, 22 p.
- Keith, Arthur, 1907, Nantahala folio: U.S. Geol. Survey Geol. Atlas, Folio 143, 11 p.
- Kellberg, J. M., and Grant, L. F., 1956, Coarse conglomerates of the middle Ordovician in the Southern Appalachian Valley: Geol. Soc. America Bull., v. 67, p. 697-716.
- Keller, F. B., 1977, Sandstone turbidites in the Tellico formation, Indian Creek embayment, Tennessee in Ruppel, S.C., and Walker, K. R., The ecostratigraphy of the middle Ordovician of the southern Appalachians (Kentucky, Tennessee, and Virginia): a field excursion: The Univ. of Tennessee, Dept. of Geol. Sci., Studies in Geology 1, p. 117-121.
- \_\_\_\_\_, ms 1980, Late Precambrian stratigraphy, depositional history, and structural chronology of part of the Tennessee Blue Ridge: Yale University, New Haven, Conn., Ph.D. dissert., 353 p.
- King, P. B., 1964, Geology of the central Great Smoky Mountains, Tennessee and North Carolina: U.S. Geol. Survey Prof. Paper 349-C, 148 p.
- \_\_\_\_\_, 1969, Tectonic map of North America with explanatory text: U.S. Geol. Survey Prof. Paper 628.
- \_\_\_\_\_, Hadley, J. B., Neuman, R. B., and Hamilton, W. B., 1958, Stratigraphy of the Ocoee series, Great Smoky Mountains: Geol. Soc. America Bull., v. 69, p. 947-966.

- King, P. B., and Ferguson, H. W., 1960, Geology of northeasternmost Tennessee: U.S. Geol. Survey Prof. Paper 311, 136 p.
- Kish, S. A., Mohr, D. W., Merschat, C. E., and Wiener, L. S., 1975, Guide to the geology of the Blue Ridge south of the Great Smoky Mountains, North Carolina: North Carolina Div. Mineral Resources, Carolina Geol. Soc. Guidebook, 49 p.
- Lesure, F. G., Force, E. R., Windolph, J. F., and Hill, J. J., 1977, Mineral resources of the Joyce Kilmer-Slickrock wilderness, North Carolina-Tennessee: U.S. Geol. Survey Bull. 1416, 89 p.
- Livingston, John E., ms 1977, Structural analysis of the Great Smoky thrust sheet along the Little Tennessee River, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 107 p.
- McLaughlin, R. E., and Hathaway, D. J., 1973, Fossils in the Murphy marble (abs.): Geol. Soc. America Abs. with Programs, v. 5, no. 5, p. 418-419.
- Marie, James R., ms 1963, Stratigraphy and structure of the Millican Creek area, Sevier County, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 37 p.
- Merschat, C. E., and Wiener, L. S., 1973, Provisional geologic map of the Ocoee supergroup, southwestern North Carolina and southeastern Tennessee (Abs.): Geol. Soc. America Abs. with Programs, v. 5, no. 5, p. 420.
- Mohr, D. W., ms 1972, Stratigraphy, structure, and metamorphism of the eastern part of the Fontana Lake reservoir, Great Smoky Mountains, North Carolina: Univ. Chicago, Chicago, Ill., Ph.D. dissert., 143 p.
- \_\_\_\_\_, 1975, Geologic map of Noland Creek quadrangle, North Carolina: North Carolina Div. Mineral Resources, Map GM 158-NE, scale 1:24,000.
- Neuman, R. B., 1955, Middle Ordovician rocks of the Tellico-Sevier Belt, eastern Tennessee: U.S. Geol. Survey Prof. Paper 274-F, p. F141-F178.
- \_\_\_\_\_, 1960, Geology of the Wildwood quadrangle, Tennessee: U.S. Geol. Survey Quad. Map GQ-131, scale 1:24,000.
- \_\_\_\_\_, and Nelson, W. H., 1965, Geology of the western Great Smoky Mountains, Tennessee: U.S. Geol. Survey Prof. Paper 349-D, 81 p.

- Neuman, R. B., and Wilson, R. L., 1960, Geology of the Blockhouse quadrangle, Tennessee: U.S. Geol. Survey Geol. Quad. Map GQ-131, scale 1:24,000.
- Oriel, S. S., 1950, Geology and mineral resources of the Hot Springs window, Madison County, North Carolina: North Carolina Div. Mineral Resources Bull. 60, 70 p.
- Poppelreiter, B. A., ms 1980, Structural fabric study along Tellico River, eastern Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 89 p.
- Powell, C. McA., 1979, A morphological classification of rock cleavage: Tectonophysics, v. 58, p. 21-34.
- Price, R. A., and Mountjoy, E. W., 1970, Geologic structure of the Canadian Rocky Mountains between Bow and Athabasca Rivers — a progress report: Geol. Assoc. Canada Spec. Paper 6, p. 7-25.
- Rich, J. L., 1934, Mechanics of low-angle overthrust faulting as illustrated by Cumberland thrust block, Virginia, Kentucky, and Tennessee: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 1643-1654.
- Rodgers, John, 1953, Geological map of east Tennessee with explanatory text: Tennessee Dept. of Conservation, Div. of Geology, Bull. 58, pt. 2, 186 p.
- \_\_\_\_\_, 1970, The tectonics of the Appalachians: New York: Interscience Publishers, 271 p.
- Roeder, Dietrich, Gilbert, O. E., and Witherspoon, W. D., 1978, Evolution and macroscopic structure of Valley and Ridge thrust belt, Tennessee and Virginia: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci., Studies in Geology 2, 25 p.
- \_\_\_\_\_, and Witherspoon, W. D., 1978, Palinspastic map of east Tennessee: Am. Jour. Sci., v. 278, p. 543-550.
- \_\_\_\_\_, Witherspoon, W. D., and Horton, Robert, 1980, Fold-discordant thrusting in the Valley and Ridge — kinematics and possible dynamics (abs.): Geol. Soc. America Abs. with Programs, v. 12, no. 4, p. 207.
- Samman, N. F., ms 1975, Sedimentation and stratigraphy of the Rome formation in east Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Ph.D. dissert., 337 p.
- Shanmugam, Ganapathy, and Walker, K. R., 1978, Tectonic significance of distal turbidites in the middle Ordovician Blockhouse and lower Sevier formation in east Tennessee: Am. Jour. Sci., v. 278, p. 551-578.

- Sutton, Thomas, ms 1971, Relationship between metamorphism and geologic structure along the Great Smoky fault system, Parksville quadrangle, Polk and Bradley counties, Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Ph.D. dissert., 148 p.
- Swingle, G. D., 1973, Structural geology of Knox County, Tennessee in Geology of Knox County: Tennessee Dept. of Conservation, Div. of Geology, Bull. 70, p. 63-73.
- \_\_\_\_\_, Harper, D. D., Palmer, R. A., and Milici, R. C., 1967, Geologic map of the Boyds Creek quadrangle: Tennessee Dept. of Conservation, Div. of Geology, Geologic Map GM 156-SW, scale 1:24000.
- Tegland, Edward R., 1978, Seismic investigations in East Tennessee, Tennessee Dept. of Conservation, Div. of Geology, Bull. 78, 68 p.
- U.S. Geological Survey, 1980, CDP data in the Appalachian overthrust — set no. 1: Open file from National Geophysical and Solar-Terrestrial Data Center, National Oceanographic and Atmospheric Administration, Boulder, Colorado.
- Walker, K. R., 1977, A brief introduction to the ecostratigraphy of the middle Ordovician of east Tennessee (southern Appalachians, U.S.A.) in Ruppel, S. C., and Walker, K. R., The ecostratigraphy of the middle Ordovician of the southern Appalachians (Kentucky, Tennessee, and Virginia): a field excursion: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci., Studies in Geology 1, p. 12-17.
- \_\_\_\_\_, and Keller, F. B., 1977, Tellico formation: submarine fan, proximal to distal turbidite environments in Ruppel, S. C., and Walker, K. R., The ecostratigraphy of the middle Ordovician of the southern Appalachians (Kentucky, Tennessee, and Virginia): a field excursion: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci., Studies in Geology 1, p. 134-140.
- Watkins, J. S., 1964, Regional geologic implications of the gravity and magnetic fields of a part of eastern Tennessee and southern Kentucky: U.S. Geol. Survey Prof. Paper 516-A, 17 p.
- Wiener, L. S., 1976, Great Smoky group and Murphy Belt strata — Paleozoic or Precambrian deposits? (abs.): Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 299.
- Winkler, Helmut G. F., 1976, Petrogenesis of Metamorphic Rocks (fourth ed.): New York, Springer-Verlag, 1976, 334 p.
- Wise, Thomas, ms 1980, Significance of solution cleavage in the Chapman Ridge anticline, east Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 106 p.

Woollard, G. P., Chairman, Joesting, H. R., and others, 1964, Bouguer gravity anomaly map of the United States: U.S. Geol. Survey.

Yust, W. W., ms 1976, A mesoscopic fabric analysis of a portion of the Tellico-Sevier belt of east Tennessee: The Univ. of Tennessee, Knoxville, Dept. of Geol. Sci. Master's thesis, 106 p.



## APPENDICES

## APPENDIX A

### TECTONIC MICROFABRIC IN GREAT SMOKY MOUNTAINS REGION

Rocks from part of the Appalachian orogen, ranging from unmetamorphic to the amphibolite facies of metamorphism, were examined to determine differences in tectonic style at the microscopic scale. Approximately 85 outcrop samples and stream pebbles were collected over a 750 square km area (fig. 18).

The study area can be divided into three regions based on the metamorphism: a region external to (northwest of) the trace of the Miller Cove fault; a region between Miller Cove and Brushy Mountain faults; and a region internal to the Brushy Mountain fault. Rocks in the first region are unmetamorphic, or show metamorphism only evident from x-ray diffraction studies of layer silicates. Rocks in the second region have experienced lower greenschist facies regional metamorphism. Rocks of the third region range in metamorphic grade from upper greenschist to amphibolite facies.

#### Microfabric External to Miller Cove Fault

##### Thermal Indicators

Conodont color alteration (Epstein et al., 1979) and x-ray diffraction pattern of layer silicates (Sutton, 1973) indicate temperatures ranging from 100 to 350 degrees C, at depths of burial ranging from 3 to 12 km, have affected rocks external to the Miller Cove fault.



Figure 18. Sample locations for thin-section study.

Epstein et al. (1979) found conodont alteration indices (CAI's) in Ordovician rocks to range from 2.5 near Knoxville to 4 near the Blue Ridge front. The empirical CAI scale may be calibrated on the basis of samples from the Appalachian Plateaus region, where most of the post-Ordovician overburden is generally preserved. In that area, CAI's of 2.5 to 4 correspond to a depth range of about 3-7 km.

Rocks of Tuckaleechee Cove, in a window 10 km southeast of the main trace of the Great Smoky fault, produced a CAI of 2. The anomalously low value indicates that CAI values were established prior to Great Smoky thrusting, and that the Great Smoky thrust sheet in this area was not thicker than 4 km for any great length of time. It also suggests that sedimentary overburden on Ordovician rocks now in Tuckaleechee Cove was 3 to 4 km less than overburden on Ordovician rocks in the eastern Valley and Ridge.

The  $10\text{ \AA}$  x-ray diffraction peak of illite has been used as an indicator of the degree of very-low-grade metamorphism (Kubler, 1968; Winkler, 1976). Sutton (1973) examined the sharpness of the  $10\text{ \AA}$  illite peak in the Valley and Ridge and Blue Ridge of southeast Tennessee. A major jump in crystallinity of illite was recorded across the Great Smoky fault. However, within the Blue Ridge, no consistent variation in peak sharpness was observed, despite easterly-increasing metamorphic grade. Sutton concluded that a threshold value on the sharpness scale had been reached, beyond which higher values did not reflect improvements in crystallinity. Sutton used a different scale than Kubler (1968), but the fact that the end of improvements in illite crystallinity was reached

suggests that the boundary between very-low-grade and low-grade metamorphism (Winkler, 1976) is crossed at the Great Smoky fault. This boundary is placed between 300 and 400 degrees C (Winkler, 1976).

Sutton (1973) was able to use other x-ray diffraction techniques to show that the Indian Creek fault (probably equivalent to the Miller Cove fault in the study area) is also a major metamorphic boundary.

King (1964) placed the northwestern limit of metamorphism internal to the Miller Cove fault, because detrital biotite in rocks external to that fault shows no signs of alteration to chlorite.

### Microfabric

External to the Miller Cove fault, foliation is present mainly in middle Ordovician argillaceous limestones and calcareous clastics. It is notably faint or absent in shales in other parts of the section: Sandsuck Formation, Chilhowee Group, Rome Formation, and Conasauga Group. Generally, these shales are much less calcareous than middle Ordovician rocks.

The foliation in middle Ordovician rocks is a spaced disjunctive cleavage, according to the classification of Powell (1979). "Disjunctive" refers to an absence of microfolding on the scale of the cleavage spacing. Cleavage films consist of brown films, presumably composed of clay and organic materials. The material in the film is too fine for petrographic determination of whether preferred orientation exists.

Cleavage becomes more closely spaced toward the top of the Lenoir formation on the limbs of the Chapman Ridge anticline (Wise, 1980) in

the Knoxville plate. This could be due to one or more of the following factors:

1. Unidentified compositional changes in the Lenoir;
2. Greater mean stress on the inner arc of buckling in the competent Holston Formation, which overlies the Lenoir; or
3. Influence by the impermeable Holston cover on flux of the dissolving fluids.

Wise (1980) considered the second factor to be most important. Strength of foliation varies considerably between different outcrops in middle Ordovician clastics of the Dumplin Valley plate, but so far no relationship to structure has been identified.

Foliation in the Knoxville plate is mainly found in the Lenoir limestone, a cobbly, argillaceous limestone. In the thrust plates to the south (Dumplin Valley and Guess Creek) foliation occurs in the Tellico-Sevier formations, a series of calcareous shales, siltstones, and fine sandstones. Lithologic differences account for differences in the typical cleavage morphology in the different areas.

The Lenoir Limestone contains beds of relatively pure limestone with occasional boudinage, which grade into beds of clay-poor limestone nodules interspersed with argillaceous limestone. Interbedded is limestone which is generally argillaceous, without nodules. Wise (1980) found that cleavage has anastomosing, evenly spaced character within argillaceous limestone, but that cleavage films tend to gather together to veer around nodules or pass through a gap in a clay-free limestone bed.



In the Lenoir, fossils are truncated against cleavage surfaces, indicating that cleavage formation involved removal of carbonate material by dissolution. Pressure shadows of carbonate vein fibers, rimming chert grains, with fiber orientations indicating extension in the plane of cleavage, also show that carbonate was mobile during compressional deformation.

About 16 samples of the middle Ordovician clastics of the Dumplin Valley and Guess Creek plates were examined in thin section in this study. The rocks consist of laminated clay, silt and fine sand, with brown seams parallel to bedding whose concentration varies from bed to bed. The seams are presumably bedding stylolites, composed of clay and organic material, probably localized at horizons originally rich in this material.

Cleavage is most closely spaced where bedding stylolites are most densely concentrated. Spacing is typically on the order of 0.1 mm.

In addition, second-order cleavage is present in some samples. A second-order cleavage film is internally composed of very closely spaced first-order films. Spacing between second-order films is on the order of 1 cm. Second-order cleavage is best developed where cleavage intersects particularly thick bedding stylolites.

In siltstones and shales, cleavage has anastomosing morphology. In one sample, each cleavage film veered between two well-defined orientations about 20 degrees apart. In sandstones cleavage grades from anastomosing to rough. In rough cleavage (Powell, 1979), some sand grains are totally enveloped by a cleavage film, and films generally can be traced only for short distances.

## Microfabric between Miller Cove and Brushy Mountain Faults

### Thermal Indicators

X-ray diffraction studies by Sutton (1971) give detail on mineralogy of the layer silicates in the Indian Creek (Miller Cove) plate in southeast Tennessee. Fine grained rocks contain muscovite composed mainly of the 2M polymorph, with a small proportion of the 1M type. Paragonite is also present in some samples, making up more than 50% of some slates. Chlorite of the Miller Cove plate is well-crystallized, based on heat treatment and x-ray diffraction.

The metamorphic assemblage quartz-white mica-chlorite±albite±epidote is common in rocks of the Miller Cove and Dunn Creek plates (King, 1964; Hamilton, 1961). The chlorite imparts to carbon-poor rocks of the Snowbird group their greenish cast.

Metamorphic biotite occurs in some rocks at the internal edge of the Dunn Creek plate. In feldspathic sandstones of the Roaring Fork formation, south of the Gatlinburg fault, biotite is found (King, 1964). In the sample examined in thin section, from near Sugarlands, biotite occurs as green flakes which have no noticeable preferred orientation. The rock is not seen to be foliated in hand specimen. A small number of the samples collected by Neuman and Nelson (1965) from the Metcalf Phyllite contain biotite. No biotite was identified in any of the Metcalf samples thin-sectioned in this study. Occurrence of biotite sets a lower limit of about 400 degrees C on conditions of metamorphism in this region (Winkler, 1976).

### Microfabric in Miller Cove Plate

Foliation is almost universal in fine-grained rocks of the Walden Creek group in the Miller Cove plate (Hamilton, 1961; King, 1964; Sutton, 1971; Holcombe, 1973; Livingston, 1977). It is common in thin sandstone beds interbedded with finer-grained rock, but uncommon in limestones and thick-bedded sandstones.

Every subtype of spaced cleavage (Powell, 1979) is identified. The cleavage changes drastically from bed to bed, due to differences in grain size, layer thickness, and strain.

Both first and second-order cleavage (Holcombe, 1973) are developed. They occur together in many beds, but it is also common for pelitic beds to have only first-order cleavage, or for only second-order cleavage to be developed in psammitic beds. The first order cleavage is a rough to anastomosing disjunctive cleavage, with spacing the same magnitude as the grain size. It is generally confined to pelitic layers. The second order cleavage is an anastomosing to smooth disjunctive cleavage or a crenulation cleavage (zonal or discrete), commonly spaced on the order of 1 cm.

A first order cleavage is a film less than .01 mm wide. The film is mainly composed of white mica, chlorite, and disseminated opaque material. Some mica flakes are coarse enough that preferred orientation parallel to cleavage domains is microscopically observed. Holcombe (1973) analyzed the chemistry in cleavage films in rocks from Miller Cove and Dunn Creek plates of southeastern Tennessee. Using a defocused beam electron microprobe technique, he mapped chemical distribution of

areas up to 0.5 mm on a side. Each area contained a cleavage lamella and the adjacent part of the rock. Cleavage lamellae were found to be enriched in K, Al, and Ti with respect to the surrounding rock, reflecting a concentration of muscovite and rutile. Lamellae are depleted in Si, Ca, and Mn, indicating removal of quartz and ankerite (a Ca, Mg, Mn-bearing carbonate). Less significant depletion in Na and Fe reflect lowered concentrations of albite and ankerite, respectively. Holcombe states that chlorite is present both inside and outside of cleavage lamellae, but that outside the lamellae it is penninite, whereas within cleavage films it is prochlorite.

Second order cleavages appear in hand specimen as dark bands 1-3 mm wide. Microscopically, each is composed of many cleavage films, similar to first-order cleavage surfaces, spaced as closely as 0.01 mm.

Holcombe (1973) indicates that second order cleavage surfaces pass from pelitic beds into coarser beds, thinning with increasing distance into the coarse beds. Many layers fade out completely, so that spacing of second-order cleavage in the interior of a sandy bed is considerably greater than in adjacent pelitic beds. The thicker a sandy bed is, the wider is the cleavage spacing in its interior.

This relationship also holds at Cove Creek Cascades (guidebook stop 7), but fading out of second-order cleavages as they pass into sandy beds is often accomplished in a way not discussed by Holcombe. As second-order cleavage enters the sandy layer, it fans out like a river's distributaries. The many cleavage films that make up the second-order cleavage diverge around sand grains, producing a rough disjunctive morphology.

In thinly laminated sequences of sand, silt, and clay, second-order cleavage surfaces can often be traced across bedding for distances up to 15 cm (fig. 19). Cleavage refraction, in which cleavage is at a lower angle to bedding in finer-grained layers, is a consistent feature of such sequences. Over part or all of its course across the layers, cleavage also coincides with steep limbs of kinks affecting laminae. In rocks with only slight kinking, second-order cleavage is continuous where kinks are not. The cleavage surface trends across layers, not changing its width or the density of fine cleavages that compose it, whether it is coinciding with a kinked zone or crossing unbent layers. The second-order cleavage is of smooth disjunctive type where layers are unbent, but of zonal crenulation type where it crosses bent laminae.

In rocks with tighter kinking, second-order cleavage entirely coincides with kinks. In particularly tight portions of a kink, laminae are truncated against the second-order cleavage. The cleavage is described as discrete crenulation cleavage where there is truncation. A complete gradation therefore exists, from smooth disjunctive through zonal crenulation to discrete crenulation type cleavage, evidently dependent on the extent that kinks are developed.

Foliation occurs sporadically in the massive sandstone sequences of the Walden Creek group (main body of the Shields formation, for example). It is rough to anastomosing spaced cleavage. Cleavage films consist of a pale yellow, strongly birefringent layer silicate, and are free of opaque material. The mineral may be weathered chlorite intergrown with white mica, as suggested by Sutton (1971), rather than biotite or stilpnomelane.

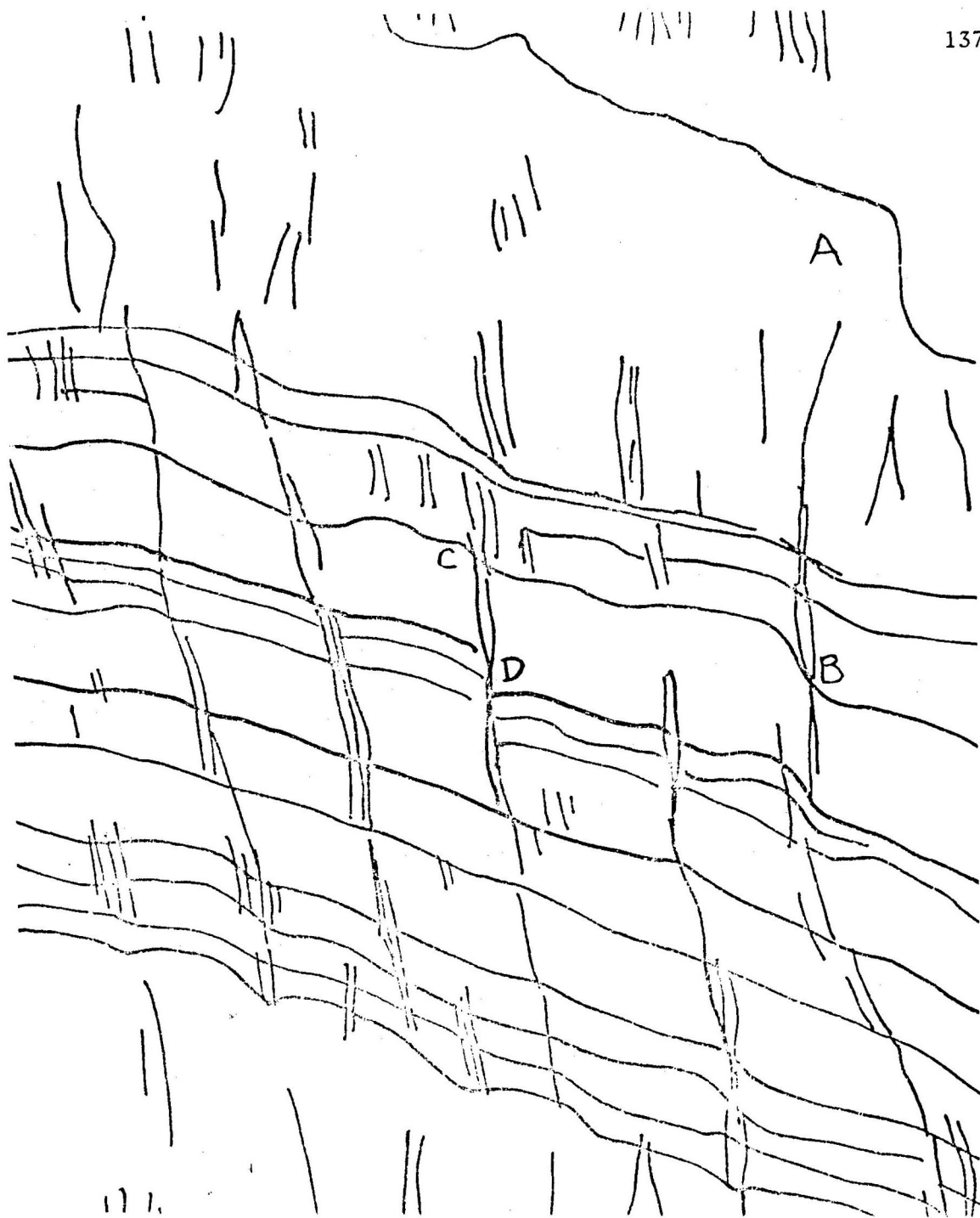


Figure 19. Line drawing of variations of second order cleavage, observed in hand specimen, Wilhite Formation, Miller Cove plate.

Different modes of second-order cleavage are visible. Region of no cleavage (A) passes into zonal crenulation cleavage (B); zonal crenulation cleavage (C) changes into discrete crenulation cleavage (D).



### Microfabric in Dunn Creek Plate

Foliation is uncommon in sandstones of the Dunn Creek plate, but commonly is present as spaced cleavage in siltstones, and as continuous cleavage in finer-grained rocks such as compose the bulk of the Metcalf Phyllite. Spaced cleavage is similar in range of morphologies to the foliation common in pelites of the Miller Cove plate, but is sometimes less obvious, and second-order cleavages are not as widespread. Possibly the foliation is less obvious simply because less dark material is present with which cleavage can be accentuated.

The Metcalf phyllite includes rocks with continuous cleavage, i.e., cleavage in which no clear domains of less-well developed foliation can be distinguished with an optical microscope. Muscovite occurs in flakes up to 0.1 mm long, and seems to be coarsest in rocks containing carbonate material. This could be due to lowered  $P_{H_2O}$  in such rocks, causing dehydration reactions producing muscovite from lower-temperature phyllosilicates to proceed more rapidly.

The main foliation in the Metcalf phyllite is a spaced cleavage in a few locations, mostly close to contacts with the massive sandstone-dark pelite facies where the Metcalf contains considerable dark material. The cleavage typically has anastomosing morphology. Second-order cleavage is observed in one sample, with marked truncation of thin quartz veins against cleavage surfaces suggesting considerable removal of material by dissolution.

Two outcrops of Metcalf phyllite (guidebook stops 4b and 5) contain rocks with highly strained to mylonitic textures. A thin section from

an outcrop between Tremont and Cades Cove shows highly polygonized sand grains. Chlorite +white mica beards appear in the pressure shadow of some grains. Flinty rocks are present at another outcrop southeast of Townsend. In thin section, most of the quartz occurs as finely laminated stringers, whereas the coarse grains present in the rock are feldspar. Fine disseminated hematite imparts a reddish color to hand specimens.

Kink bands crosscut foliation in some samples. In some thin sections, the bands are enriched in phyllosilicates and opaque material relative to surrounding rock, indicating that solution-transfer was active in production of some postfoliation fabrics.

#### Microfabric Internal to Brushy Mountain Fault

Thirty-two samples from the Brushy Mountain plate were examined in thin-section. Except for two samples from the biotite zone and three samples from the staurolite zone, all samples were from the garnet zone, based on isograd mapping by Hadley and Goldsmith (1963). The rocks differ from typical rocks external to the Brushy Mountain fault in that orientation of layer silicates, and course of layer silicate-rich domains, are little influenced by the other grains in the rock. In sandstones, detrital matrix has disappeared, in favor of white mica and biotite flakes which are little affected by sand grain boundaries. In pelitic rocks, anastomosing foliation is uncommon, not only in the case of the main foliation, but in the case of later foliations as well.

Not all rocks in the area, not even all pelitic rocks, have strong preferred orientation to layer silicates. In some samples, a preferred

orientation has been down-graded by microfolding, but in others, layer silicates are just randomly oriented. Where foliation is well developed, the smooth morphology of cleavage makes for better preferred orientation than in the bulk of samples external to the Brushy Mountain fault.

Chloritoid, although inequant, does not show preferred orientation. Chloritoid porphyroblasts are generally orders of magnitude larger than the grain size of the matrix. Biotite occurs both as equant grains, and as ovoid bodies aligned parallel to foliation. In only one pelitic specimen were platy biotite flakes seen, disposed parallel to a prominent layering. This sample had a strong crenulation cleavage overprinting the layering.

### Conclusions

Foliation is developed in all three subdivisions of the study area. In the most external region, foliation is common only in rocks containing both clay and carbonate. Cleavage films consist of sub-microscopic material, probably clay and organic material. Spaced disjunctive cleavage with anastomosing character is typical.

In the region between Miller Cove and Brushy Mountain faults, foliation affects most pelites and a few psammitic rocks. Layer silicate grains range from submicroscopic to coarse silt-sized, and show preferred orientation. Spaced disjunctive and crenulation cleavage are characteristic in the northern half of the region, whereas continuous cleavage as well as spaced cleavage make up the dominant foliation in the south. Later foliations, typically spaced crenulation cleavage, are also present in the south.

The southernmost region still contains pelitic rocks with submicroscopic layer silicates, some having little preferred orientation. However, continuous cleavage with excellent preferred orientation of sand-sized mica flakes is present in other pelites. The main distinguishing feature of the region, which applies to both psammites and pelites, is that layer silicates are not molded around the shapes of quartzofeldspathic grains, as they are to the northwest.

The effects of increasing temperature can be read in these textural differences. The main mobile constituent in the externalmost area is carbonate, whereas several constituents — the quartz, chlorite, and epidote as well as carbonate, observed in veins — are important in the middle region. The internalmost region is an area in which lattice diffusion rates become comparable to grain boundary diffusion rates (Elliott, 1973), so that grain boundaries no longer exert control over growth of layer silicates.

## APPENDIX B

### GUIDE TO SELECTED OUTCROPS IN THE BLUE RIDGE OF TENNESSEE

#### Stop 1: Folds with Axial Plane Foliation, North of Tuckaleechee Cove

Beds of slate, fine sandstone, and siltstone in the late Precambrian Wilhite Formation (Walden Creek Group) are affected by folds which trend about 50 degrees east of north (50). Folds in slates are long-limbed and angular, with wavelength to amplitude ratios as low as 1:1. Foliation, axial planar to folds, strikes 50 and dips 78 degrees southeast. A macroscopic anticline in this area, which has a similar orientation, is oblique to, and appears truncated at either end, by the Miller Cove and Dunn Creek-Rabbit Creek faults, indicating that foliation predates thrusting.

Foliation is a spaced disjunctive cleavage with anastomosing morphology. Limbs of folds bear striations, indicating slip of beds toward fold hinges during folding.

A sample from this outcrop has a K-Ar whole rock age of 450 million years (S. A. Kish, pers. comm., 1977).

#### Stop 2: Minor Folds Affecting Foliation

The late Precambrian Metcalf Phyllite (Snowbird Group) is here affected by angular postfoliation folds with wavelengths about 10-20 cm and amplitudes 2-5 cm. Folds of this style are common in the area, with axial planes which strike 10-20 and dip 70 degrees east to vertical, and

subhorizontal axes (fig. 9D, page 58). A crenulation foliation is axial planar to the folds. Its intersection with the main foliation forms a prominent lineation.

Hinge zones of this set of folds frequently host quartz-filled fractures.

The fold set is apparently unrelated to any obvious macroscopic structures.

### Stop 3: Minor Folds with Axial Plane Foliation

Siltstones and sandstones of the Metcalf are folded in this exposure, with axial planes that strike 26 and dip 24 degrees southeast, and axes which plunge down the dip of axial planes. Foliation is parallel to axial planes. Syn-foliation reclined folds are observed from this point as far east as Metcalf Bottoms (fig. 9A, page 58).

Although no major folds of this orientation are evident on published mapping, stereonet projections of poles to bedding throughout the area define a pi-axis parallel to axes of the minor folds (fig. 9B, page 58).

Near the north end of the outcrop, foliation is affected by folds similar in style and orientation to those observed at the previous stop.

### Stop 4: Contact between Great Smoky Group and Snowbird Group Strata

Rocks at the near and far ends of the tunnel were mapped as Metcalf Phyllite and Cades Sandstone, respectively, by King (1964). Metcalf at this exposure is sulfidic, and considerably darker than typical Metcalf



Phyllite. On the other end of the tunnel, still darker, sulfidic slate appears, and 70 m north of the end of the tunnel, dark slate is interbedded with massively bedded, dark gray sandstone, typical of both the Cades Formation and the Great Smoky Group. The anomalously dark and sulfidic character of the Metcalf is common near contacts with the Great Smoky Group or Cades Formation, and generally suggests that the contacts are stratigraphic.

However, in this exposure the fault interpretation of King (1964) is credited by the highly strained character of the Metcalf, as observed in thin section. Silt grains are polygonized and are rimmed by beards of chlorite and white mica.

#### Stop 5a: "Shear Cleavage" Kinks

Foliation in Metcalf Phyllite at this exposure is overprinted by a number of kink bands, which vary in dip from 25 degrees southeast to 50 degrees northwest (fig. 9C, page 58). The bands are about 0.5 cm wide, and can be traced across the outcrop for distances of 10-100 cm. Independent of the attitude of a kink, the block above each kink has been displaced to the northwest.

Quartz boudins up to 10 cm long are common in the outcrop, and many show drag at the ends where they touch the kinks.

Kink bands of this type are common in the northern belt of outcrop of the Metcalf Phyllite, that is, between the Great Smoky fault and a tabular body of sandstone assigned to the Cades formation (King, 1964), but are rarely seen in the outcrop belt to the southeast of the sandstone unit.

Since it is unlikely that all kinks originated under the same orientation of principal stresses relative to the rock body, the body of rock must have rotated relative to principal stress directions. Supposing compression remained subhorizontal during deformation, kink bands now dipping northwest must have formed earliest, in a moderately southeast-dipping position, and rotated 50 degrees into their present orientation (fig. 10, page 61).

Simple shear which could have rotated rock in this sense would have the same orientation and sense as the displacement on kinks active at any particular stage, with gently southeast-dipping slip in the reverse fault mode.

#### Stop 5b: Mylonitized Sandstone

In thin section, this rock contains sand-sized feldspar grains, surrounded by wispy shreds of quartz having undulose extinction. The reddish color in some samples is due to silt-sized inclusions of hematite.

The regional significance of this mylonite, if any, is unknown. It can be traced across the Little River immediately to the west, but does not crop out on the road 0.3 km to the east. In this belt of Metcalf rocks, between the Great Smoky fault and a tabular body of Cades sandstone, deformation is typically intense, and fine-scaled bedding not visible because of transposition.

Stop 6: Evidence for Stratigraphic Relation between  
Great Smoky and Snowbird Groups

Exposures in the jeep trail from elevation 3000 to 3400 feet show the contact between late Precambrian rocks of the Metcalf Phyllite (Snowbird group) and Thunderhead Sandstone (Great Smoky group). Lenticular-laminate bedding is observed in fine-grained rocks throughout the section, suggesting these rocks have little strain, as contrasted with Metcalf Phyllite at the previous stop.

Upwards in this exposure, fine-grained beds grade uniformly from light gray to dark gray, as thick coarse sandstone bodies become more numerous. Apart from the color change, there is little difference between fine-grained materials at the bottom and at the top of the exposure.

King (1964) believed that the Greenbrier fault separates coarse sandstones and dark pelitic rocks of the Thunderhead Sandstone, from light-gray pelitic rocks of the Metcalf Phyllite, along this north slope of Cove Mountain. He considered large, mappable bodies of Thunderhead-type sand within the Metcalf to be fault-bounded. There is no evidence of such faults in this exposure, and evidence for a stratigraphic contact appears compelling.

Stop 7a: Folded Slate, Siltstone, and Fine Sandstone  
of the Late Precambrian Wilhite Formation  
(Walden Creek Group)

Folds in this exposure range from open to close and from rounded to moderately angular. The form of folds depends on the presence and

thickness of competent sandstone interbeds. Rounded, open folds are developed mainly where thick sandstone beds are present, whereas folds with especially large ratios of amplitude to wavelength occur in thick sequences that are mostly pelitic. The folds have axial plane foliation, which strikes 85 and dips 43 degrees south. Fold axes are subhorizontal.

Both first and second-order cleavage (Holcombe, 1973) are developed. They occur together in many beds, but it is also common for pelitic beds to have only first-order cleavage, or for only second-order cleavage to be developed in psammitic beds. The first order cleavage is a rough to anastomosing disjunctive cleavage, with spacing the same magnitude as the grain size. It is generally confined to pelitic layers. The second order cleavage is an anastomosing to smooth disjunctive cleavage or a crenulation cleavage (zonal or discrete), commonly spaced on the order of 1 cm.

Second-order cleavages appear in hand specimen as dark bands 1-3 mm wide. Microscopically, each is composed of many cleavage films, similar to first-order cleavage surfaces, spaced as closely as 0.01 mm.

Holcombe (1973) indicates that, along Ocoee River in southeast Tennessee, second-order cleavage surfaces pass from pelitic beds into coarser beds, thinning with increasing distance into the coarse beds. Many layers fade out completely, so that spacing of second-order cleavage in the interior of a sandy bed is considerably greater than in adjacent pelitic beds. The thicker a sandy bed is, the wider is the cleavage spacing in its interior.

At Cove Creek Cascades, fading out of second-order cleavages as they pass into sandy beds is sometimes accomplished by fanning out of

films like a river's distributaries. The many cleavage films that make up the second-order cleavage diverge around sand grains, producing a rough disjunctive morphology.

In thinly laminated sequences of sand, silt, and clay, second-order cleavage surfaces can often be traced across bedding for distances up to 15 cm. Cleavage refraction, in which cleavage is at a lower angle to bedding in finer-grained layers, is a consistent feature of such sequences. Over part or all of its course across the layers, cleavage also coincides with steep limbs of kinks affecting laminae (fig. 19, page 137). In rocks with only slight kinking, second-order cleavage is continuous where kinks are not. The cleavage surface trends across layers, not changing its width or the density of fine cleavages that compose it, whether it is coinciding with a kinked zone or crossing unbent layers. The second-order cleavage is of smooth disjunctive type where layers are unbent, but of zonal crenulation type where it crosses bent laminae.

In rocks with tighter kinking, second-order cleavage entirely coincides with kinks. In particularly tight portions of a kink, laminae are truncated against the second-order cleavage. The cleavage is described as discrete crenulation cleavage where there is truncation. A complete gradation therefore exists, from smooth disjunctive through zonal crenulation to discrete crenulation type cleavage, evidently dependent on the extent that kinks are developed.

Veins, composed of various proportions of ankerite, calcite, chlorite, epidote, and quartz, are present in this exposure. Some

tabular calcite veins, at a high angle to bedding, are offset in a sense compatible with flexural-slip formation of folds.

Other veins, composed of quartz + carbonate + epidote, have very irregular boundaries. Near the northwest end of the exposure, a lens of rock about 10 m long, which is bounded by faults, has a high concentration of such veins.

Faults in this exposure, which crosscut folds that have axial plane foliation, strike 85 and dip gently to moderately southeast. Reverse separation of about 30 cm is indicated by offset of marker beds on one low-dipping fault near the south end of the exposure.

#### Stop 7b: Polyphase Folding in Slates and Boulder Conglomerates of the Wilhite Formation

The rocks here are mostly fine sandstone and siltstone with ankerite cement, interbedded with dark slate; however, a few boulders of limestone, up to 1.5 m in diameter, are present near the center of the exposure. Boulders are composed of sand-sized single crystal sparite grains with rounding, in a micrite matrix. Some sparite grains have small quartz inclusions. The origin of this rock type is not understood.

At least two generations of folding are visible in this exposure. Foliation is axial planar to the first set of folds, and near the northwest end of the exposure is rotated, due to the second phase of folding, about a subhorizontal, northeast-trending axis. Small, angular folds affecting foliation are observed near the northwest end of the outcrop, and seem to be parasitic to the large-scale second-generation fold.



Southeast-dipping faults crosscut both fold sets. The kinematic sequence is similar to that developed on the basis of macroscopic structure (p. 48).

Stop 8: Folded and Faulted Strata in the  
Great Smoky Thrust Plate (Footwall of  
Miller Cove Fault)

Carbonate-cemented siltstones and fine-grained sandstones of the Sandsuck formation (Walden Creek Group, late Precambrian) here are in the footwall of the Bogle Spring fault, a fault within the Miller Cove plate which has anticlinal structure in its upper block.

In this exposure, a fault plane striking 130 and dipping 20 degrees northeast cuts up-section to the north in its hanging wall. The hanging wall structure is a transported ramp, in which the open folding is completely due to the attitude of the initial break. At the position of the folds in the hanging wall, the fault rides parallel to bedding in the footwall; however, in a separate exposure only 20 m to the south, beds which appear to be in the footwall of the fault are folded. Axial planes of these folds strike 30 and dip 50 degrees southeast; axes plunge 10 degrees northeast. These folds have an attitude similar to the major syncline which dominates the Miller Cove plate in this area.

Faint foliation, striking northeast and dipping steeply is visible in an exposure 100 m to the north, southeast of the road bridge.

Stop 9: Subhorizontal Folds in Pigeon Siltstone

Siltstones and fine sandstones of the Pigeon Siltstone (Snowbird Group, late Precambrian) are here deformed into subhorizontal folds with

southeast-dipping axial planes. The sheet dip of this section is to the northwest.

East of this outcrop, strike of bedding and trend of subhorizontal fold axes swing to an easterly direction. Although foliation is axial planar to folds seen in this exposure, it is oblique to axial planes of subhorizontal folds farther east, since its average orientation does not change between the two areas.

#### Stop 10: Steeply Southeast Plunging, Inclined Folds in Pigeon Siltstone

Well-laminated slates, siltstones, and fine sandstones are deformed by open, rounded folds whose axes plunge steeply southeast. Evident in this outcrop. Foliation plots in the axial plane of these folds, striking 21 and dipping 78 degrees southeast.

Macroscopic equivalents of these folds are evident from gradual changes in attitude of steeply-dipping beds in this area, between northeasterly and easterly strikes. A lithologic unit mapped by Hamilton (1961) within the Pigeon also seems to be deflected by folds of this attitude.

Although the axial planar relation of foliation to subhorizontal folds, seen at the last stop, is a local feature, foliation does appear consistently to be axial planar to steeply plunging folds.

Layer silicates in rocks of this exposure are finer and less well-oriented than in the Metcalf Phyllite to the southwest. This may be due to less total strain, especially because composition, grain size, and grade of metamorphism are similar.

Kink bands, up to 1 cm thick, dip gently north throughout the exposure. Movement of the top block is toward the southeast. The kinks are darker than surrounding rock, due to relative enrichment in opaque material.

#### Stop 11: Polyphase Folding in Pigeon Siltstone

Bedding is visible as laminations in siltstone and fine sandstone between 50 and 70 m south of the north end of this exposure. Sheet dip varies from subhorizontal in the north end of this interval to steeply easterly at the south end. Fold axes have easterly trends and rotate with sheet dip of bedding. Although the main foliation is not affected, a faint spaced cleavage seems affected even by the earlier, small scale fold set.

Stop 12: Lithologies Mapped by King (1964) as Snowbird Group,  
Near a Problematic Contact with the Great Smoky Group

#### Location a

Interbedded coarse sandstones and black sulfidic slates. This material is similar to rocks of the Anakeesta, Elkmont, and Thunderhead formations of the Great Smoky Group. They are scarce in the main body of the Snowbird Group.

#### Location b

Massive, pyritic sandstone with internal lenticular laminate bedding. The massive character and grain size are typical of the Thunderhead Formation, although the sedimentary structures resemble structures in nearby exposures of Pigeon Siltstone.

Location c

Dark siltstone with lenticular laminations of light sand. Both materials are quite sulfidic, like dark pelitic rocks of the Great Smoky Group, although reddish weathering in this section is unlike the mottled yellows and reds typical, for example, of the Anakeesta Formation. Sand has carbonate matrix, again atypical of the Great Smoky Group, but known from Snowbird and Walden Creek groups.

Near the southeast end of the exposure, blanketed by kudzu in summer months, is the contact with the Thunderhead Sandstone, mapped by King as the Greenbrier fault. The writer was unable to locate a mylonite mentioned by King (1964, p. 108). A distinctive, breccia-like lithology does appear close to the contact, but in thin section it turns out to be siltstone containing irregular carbon-free, carbonate + layer silicate regions (concretions? burrows?).

Some variation in strike of nearly vertical beds is observed in this exposure, again indicating folding around steep-plunging axes. Slickensides on bedding indicate a combination of right-lateral and reverse slip. These may belong to the same set taken by King (1964) as evidence for sense of movement on the Gatlinburg fault. The striations are also compatible with flexural slip during formation of the steeply plunging fold set.

# APPENDIX C

## MILEAGE LOG FOR APPENDIX B

| Interval | Cumulative<br>(miles) |                                                                                                                                                                                                                                                             |
|----------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0      | 0.0                   | University of Tennessee Geology and Geography building.                                                                                                                                                                                                     |
| 0.2      | 0.2                   | Left on Cumberland Avenue (U.S. 11-70).                                                                                                                                                                                                                     |
| 1.0      | 1.2                   | Junction U.S. 129. Turn left.                                                                                                                                                                                                                               |
| 1.3      | 2.5                   | Exposures of middle Ordovician Lenoir Formation on left.                                                                                                                                                                                                    |
| 0.4      | 2.9                   | Exposures of middle Ordovician Holston Formation on left.                                                                                                                                                                                                   |
| 0.3      | 3.2                   | Chapman Ridge Sandstone on left.                                                                                                                                                                                                                            |
| 0.3      | 3.5                   | Ottosee Shale on right.                                                                                                                                                                                                                                     |
| 0.3      | 3.8                   | Folded Ottosee Shale on left. Folds are parasitic to Chapman Ridge anticline.                                                                                                                                                                               |
| 1.9      | 5.5                   | Cross Stock Creek embayment of Fort Loudon Lake.                                                                                                                                                                                                            |
| 0.3      | 5.8                   | Folded Ottosee Shale on left.                                                                                                                                                                                                                               |
| 1.3      | 7.1                   | Cross Little River. Exposures of Knox Group carbonates on left.                                                                                                                                                                                             |
| 6.3      | 13.4                  | Junction Maryville bypass (U.S. 129) and State Route 73. Bear left of 73. View of Great Smoky Mountains. The near range is Chilhowee Mountain, underlain by Chilhowee Group quartzites; the farther ranges are underlain by rocks of the Great Smoky Group. |
| 18.6     | 24.9                  | Approximate trace of Great Smoky fault at front of Chilhowee Mountain. Exposures of Sandsuck Formation ahead on right.                                                                                                                                      |

|     |      |                                                                                                                                                                                                                                  |
|-----|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.7 | 25.6 | Quartzites of Chilhowee Group are exposed on the opposite side of the Little River to the left.                                                                                                                                  |
| 0.8 | 26.4 | Junction with Foothills Parkway. Continue on State Route 73.                                                                                                                                                                     |
| 0.4 | 26.8 | Lower Cambrian Shady Dolomite on right and left.                                                                                                                                                                                 |
| 0.4 | 27.2 | Sandstone of Walden Creek Group in Miller Cove plate, exposed on right.                                                                                                                                                          |
| 1.0 | 28.2 | STOP 1. Narrow turnout on left side of State Route 73. Outcrops are mainly on the right side.                                                                                                                                    |
| 0.4 | 28.6 | Sandstone of Walden Creek Group on right.                                                                                                                                                                                        |
| 0.5 | 29.1 | Folded fine-grained strata of Walden Creek Group in right.                                                                                                                                                                       |
| 0.7 | 29.8 | Sandstones and conglomerates of Walden Creek Group on right, with graded bedding.                                                                                                                                                |
| 0.3 | 30.3 | Enter Tuckaleechee Cove. Carbonates of Walden Creek are exposed in an excavation of a small hill ahead on the right.                                                                                                             |
| 0.4 | 30.7 | Cross Great Smoky fault into window.                                                                                                                                                                                             |
| 0.7 | 31.4 | Carbonates of Ordovician Knox Group in cliffs to left.                                                                                                                                                                           |
| 0.6 | 32.0 | Knox Group exposed in roadcuts.                                                                                                                                                                                                  |
| 2.0 | 34.0 | Sunoco station on left. Junction Wears Valley Road. Continue ahead on State Route 73.                                                                                                                                            |
| 0.6 | 32.6 | Folded Knox Group visible in cliffs to left.                                                                                                                                                                                     |
| 2.8 | 34.8 | Knox carbonates, middle Ordovician Blockhouse Shale, and upper Precambrian Snowbird Group (Metcalf Phyllite) exposed in succession on the right. King (1964) has described this near-outcrop of the Great Smoky fault in detail. |
| 0.8 | 35.6 | Entrance to Great Smoky Mountains National Park.                                                                                                                                                                                 |



|     |      |                                                                                                                                                             |
|-----|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.4 | 36.0 | Exposures of Metcalf Phyllite on right. "Shear cleavage" similar to that in stop 5a is developed.                                                           |
| 0.3 | 36.3 | Junction with Laurel Creek Road. Turn right toward Cades Cove.                                                                                              |
| 0.5 | 36.8 | Massive sandstone exposures on left (Cades Formation).                                                                                                      |
| 1.8 | 38.6 | Cross Laurel Creek. Two-car turnout on left. STOP 2. Outcrop is up the road about 15 m on right.<br><br>Retrace path toward Townsend.                       |
| 1.1 | 39.7 | STOP 3. Cut in Metcalf Phyllite on right. Best parking place is at stop 4.                                                                                  |
| 0.4 | 40.3 | STOP 4. Parking on left side of road, just before tunnel.                                                                                                   |
| 1.2 | 41.5 | Junction with State Route 73. Continue ahead on 73 toward Gatlinburg.                                                                                       |
| 2.1 | 43.6 | STOP 5. Two-car gravel turnout on left. Stop 5a is a prominent rock overhang next to the turnout; stop 5b is a moss-overgrown cut 0.2 mile toward Townsend. |
| 1.8 | 45.4 | Cross Little River.                                                                                                                                         |
| 0.7 | 46.1 | Meigs Creek falls on right.                                                                                                                                 |
| 1.1 | 47.2 | The Sinks are on the right. Cross Little River.                                                                                                             |
| 2.0 | 49.2 | Metcalf Bottoms picnic area on left. Turn left into picnic area. Cross Little River.                                                                        |
| 1.3 | 50.5 | Leaving Great Smoky Mountains National Park. Outcrops of Metcalf Phyllite in gap.                                                                           |
| 0.4 | 50.9 | Saprolite of Walden Creek Group in Miller Cove plate on right. Enter Wear Cove window and cross Great Smoky fault at bottom of hill.                        |
| 1.1 | 52.0 | Junction with Wears Valley Road. Turn right towards Gatlinburg.                                                                                             |

|     |      |                                                                                                                                                                                                |
|-----|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.6 | 53.6 | Wears Valley Methodist Church and Phillips 66 station on left.                                                                                                                                 |
| 0.2 | 53.8 | Sign for Covemont Church. Turn right on gravel road.                                                                                                                                           |
| 1.4 | 55.2 | Covemont Church. Bear left.                                                                                                                                                                    |
| 0.1 | 55.3 | Immediate right. Enter forest.                                                                                                                                                                 |
| 0.1 | 55.4 | Bear right.                                                                                                                                                                                    |
| 0.2 | 55.6 | Large wood and stone house on left, in open area.<br>Jeep trail bears right. STOP 6 is about two miles up this jeep trail, on the side of Cove Mountain.<br>Retrace path to Wears Valley Road. |
| 1.8 | 57.4 | Junction with Wears Valley Road. Turn right.                                                                                                                                                   |
| 0.9 | 58.3 | Exposure of Knox dolomite, beneath Great Smoky fault, on left.                                                                                                                                 |
| 0.2 | 58.5 | Float chips of fine-grained Walden Creek strata in bank on right.                                                                                                                              |
| 0.6 | 59.1 | Sandstones and graded-bed conglomerates of Shields formation, Walden Creek Group, on left.                                                                                                     |
| 0.7 | 59.8 | STOP 7a. Large roadcuts in Wilhite Formation on left.                                                                                                                                          |
| 0.4 | 60.2 | Bridge at north end of stop 7a cut. Cross Cove Creek, below cascades.                                                                                                                          |
| 0.7 | 60.9 | STOP 7b. Large roadcuts in Wilhite Formation on right.                                                                                                                                         |
| 0.2 | 61.1 | End of Stop 7b cut.                                                                                                                                                                            |
| 0.1 | 61.2 | Gravel road turnoff on left, marked by green dumpsters. Turn left.                                                                                                                             |
| 0.8 | 62.0 | Junction with Walden Creek Road. Continue across intersection.                                                                                                                                 |

|     |      |                                                                                                                                |
|-----|------|--------------------------------------------------------------------------------------------------------------------------------|
| 0.5 | 62.5 | Road forks. Bear right.                                                                                                        |
| 1.4 | 63.9 | STOP 8. Roadcuts on right side of road, 100 m short of a bridge.<br><br>Retrace path to junction with Walden Creek Road.       |
| 1.9 | 65.8 | Junction with Walden Creek Road. Turn left.                                                                                    |
| 0.5 | 66.3 | Intersection with Wears Valley Road. Continue straight.                                                                        |
| 2.8 | 69.1 | Intersection with U.S. 441. Turn right toward Gatlinburg.                                                                      |
| 3.2 | 72.3 | Leave town of Pigeon Forge.                                                                                                    |
| 0.5 | 72.8 | Caney Creek road exit. Park here for STOP 9, about 0.2 miles ahead on right side of U.S. 441.                                  |
| 0.4 | 73.2 | Gnatty Branch exit on left. Turn left. Cross Little Pigeon River. Left on opposite side of bridge on U.S. 441 North.           |
| 0.5 | 73.7 | Large turnout on left. STOP 10 is large roadcut on right side of the road.                                                     |
| 4.1 | 74.1 | Entering Pigeon Forge. Cross Little Pigeon River. Take first left after bridge, then turn left on U.S. 441 towards Gatlinburg. |
| 0.6 | 74.7 | Pass Caney Creek Road exit again.                                                                                              |
| 1.4 | 76.1 | Huskey Grove Branch exit. Leave U.S. 441 and cross Little Pigeon River. Left on northbound U.S. 441 again.                     |
| 0.8 | 76.9 | Large turnout on left beyond left bend in road. STOP 11 on right side of road.                                                 |
| 0.7 | 77.6 | Bridge at Gnatty Branch exit. Turn left and cross Little Pigeon River. Left again on U.S. 441 South toward Gatlinburg.         |
| 3.4 | 81.0 | Roadcuts on right just before bridge across Little Pigeon River are location a of STOP 12.                                     |

- |     |      |                                                                                             |
|-----|------|---------------------------------------------------------------------------------------------|
| 0.1 | 81.1 | Exit for Gatlinburg bypass. Bear right and park just beyond exit for location b of STOP 12. |
|     |      | Return to U.S. 441 South into Gatlinburg.                                                   |
| 0.2 | 81.3 | Massive sandstone outcrops on left.                                                         |
| 0.6 | 81.9 | Municipal parking lot of Gatlinburg, just beyond Hillbilly Golf. Location c of STOP 12.     |

## APPENDIX D

### EXPLANATION FOR PLATES

#### Plates I and II: Structure Sections

Dot pattern: Grenville-age basement. Black: Cambro-Ordovician Knox group. In sections 7 and 8, black also represents ?Cambrian to Ordovician Murphy, Andrews, and Nottely formations, exposed in the Murphy syncline. Dashed lines: faults.

Lithologic units are designated by the following symbols:

#### Ocoee Supergroup (Upper Precambrian):

ou Ocoee, undifferentiated

#### Snowbird Group

su Snowbird, undifferentiated

sw Wading Branch Fm.

sl Longarm Fm.

srf Roaring Fork Ss.

sp Pigeon Slts.

srb Rich Butt Ss.\*

sm Metcalf Phyllite

#### Great Smoky Group

gu Great Smoky, undifferentiated

gch Copperhill Fm.

gw Wehuttty Fm.

ghg Hughes Gap Fm.

gho Hothouse Fm.

gd Dean Fm.

---

\*Not formally assigned to any group.

|      |                                                            |
|------|------------------------------------------------------------|
| gbg  | Boyd Gap Fm.                                               |
| gbb  | Buck Bald Fm.                                              |
| gt   | Thunderhead Ss. (includes some Elkmont Fm. and Cades Ss.*) |
| gan  | Anakeesta Fm.                                              |
| ganu | upper tongue                                               |
| ganl | lower tongue                                               |
| gam  | Ammons Fm.                                                 |

### Walden Creek Group

|     |                                |
|-----|--------------------------------|
| wu  | Walden Creek, undifferentiated |
| wsh | Shields and Licklog Fms.       |
| ww  | Wilhite Fm.                    |
| wss | Sandsuck Fm.                   |

### Murphy Belt "Group" (Precambrian to Ordovician?)

|         |                                   |
|---------|-----------------------------------|
| mn      | Nantahala Fm.                     |
| mt      | Tusquitee Qtzt.                   |
| mb      | Brasstown Schist                  |
| (black) | Murphy, Andrews, and Nottely Fms. |
| mmb     | Mineral Bluff Fm.                 |

### Chilhowee Group (?Precambrian and Cambrian)

|    |                              |
|----|------------------------------|
| cl | Cochran Fm.                  |
| cu | remainder of Chilhowee Group |

### Cambrian and Ordovician Strata

|         |                                     |
|---------|-------------------------------------|
| €sr     | Shady Dolostone and Rome Fm.        |
| €c      | Conasauga Group                     |
| (black) | Knox Group (Cambrian to Ordovician) |
| Ot      | Tellico Fm.                         |

In Plates I, II, and III, numerals are used to identify faults as follows:

|   |                |   |              |
|---|----------------|---|--------------|
| 1 | Saltville      | 3 | hypothetical |
| 2 | Dumplin Valley | 4 | Guess Creek  |



|    |                            |    |                       |
|----|----------------------------|----|-----------------------|
| 5  | Great Smoky                | 18 | Chunky Gal            |
| 6  | Miller Cove                | 19 | Shope Fork            |
| 7  | Dunn Creek                 | 20 | Dahlonega             |
| 8  | Brushy Mountain (see text) | 21 | Meadow Creek Mountain |
| 9  | Greenbrier                 | 22 | Holston Mountain      |
| 10 | Pulaski                    | 23 | Middle Creek          |
| 11 | Dunham Ridge               | 24 | Mingus                |
| 12 | Cold Springs               | 25 | hypothetical          |
| 13 | Chestuee                   | 26 | Bogle Spring          |
| 14 | Hayesville                 | 27 | Happy Hollow          |
| 15 | Mary King Mountain         |    |                       |
| 16 | Beaver Valley              |    |                       |
| 17 | Knoxville                  |    |                       |

### Plate III: Tectonic Map

Scale is 1:500,000. Dot pattern: Grenville-age basement. Shaded: Cambro-Ordovician Knox Group (with Murphy addition mentioned previously). Black: ultramafic rocks. Geology after Hardeman et al. (1966), Hadley and Nelson (1971), Merschlat and Wiener (1973), and Georgia Geological Survey (1976).

Thick lines represent faults, dashed where hypothetical; large numerals are in hanging wall of each fault. Thick lines with hachures are normal faults; hachures on downthrown block. Thin line is top of Great Smoky Group and base of informally designated Murphy Belt group (outcropping in Murphy syncline).

Guidebook stops (Appendices B and C) are located by small numerals.

Upper-case letters represent locations referred to in text, as follows:

|    |                      |    |                    |
|----|----------------------|----|--------------------|
| B  | Brush Creek Mountain | C  | Chilhowee Mountain |
| BK | Babbs Knobs          | CB | Caney Branch       |
| BS | Big Springs          | CC | Cades Cove         |
| BY | Bryson City          | CK | Cherokee           |

|    |                       |    |                    |
|----|-----------------------|----|--------------------|
| CL | Cleveland             | MB | Mineral Bluff      |
| CS | Cove Creek Cascades   | MC | Millican Creek     |
| CV | Cove Mountain         | MD | Madisonville       |
| CW | Calderwood            | MF | Metcalf Bottoms    |
| D  | Denton                | MG | Maggie             |
| DD | Douglas Dam           | MY | Maryville          |
| DL | Dellwood              | N  | Newport            |
| E  | English Mountain      | PF | Pigeon Forge       |
| FC | Fighting Creek Gap    | PG | Porterfield Gap    |
| G  | Gatlinburg            | RC | Richardson Cove    |
| GP | Greenbrier Pinnacle   | RD | Raven Den          |
| GY | Mount Guyot           | S  | Sugarloaf Mountain |
| H  | Hewitt                | TC | Tuckaleechee Cove  |
| HS | Hot Springs           | TP | Tellico Plains     |
| IC | Indian Creek          | V  | Vann Cliff         |
| K  | Knoxville             | W  | Webb Mountain      |
| LC | Mount Leconte         | WB | Wayah Bald         |
| LM | Little Mountain       | WC | Wear Cove          |
| M  | Meadow Creek Mountain |    |                    |

#### Plate IV: Restoration of Part of Section 1

Symbols as in Plates I and II. Refer to discussion of Pulaski plate in Chapter 1 for explanation.

#### Plate V: Major Folds and Reference Zones

Base after Plate III. Unnamed folds are designated by letters for easy reference in Table I (page 76). Types of arrows symbolize age of folds as follows:

→ prefoliation

→ syn-foliation (the dominant foliation in an area)

➡ postfoliation

→ constraints on age unavailable

Heavy lines indicate boundaries between reference zones.

## VITA

William Dale Witherspoon was born in Knoxville, Tennessee on July 10, 1954. He attended Mount Olive Elementary School and was graduated from Doyle High School in 1971.

He entered New College, Sarasota, Florida in January, 1972. He spent three months each in the Netherlands, Ghana, and Pennsylvania doing off-campus study, related to a degree program in Religious Studies. He received the Bachelor of Arts degree from New College in 1975.

Mr. Witherspoon entered the Graduate School at The University of Tennessee, Knoxville, in September 1975. He accepted a teaching assistantship in geology in the spring of 1976. Following his Master's oral exams in fall 1976, he elected to bypass the Master's degree and entered the Ph.D. program. He received a Gulf Foundation Graduate Fellowship in the Geological Sciences in the fall of 1978. He resigned the fellowship in January, 1980, to accept a temporary appointment as instructor in Geosciences at The University of Tennessee, Chattanooga.

Mr. Witherspoon is currently employed at Bellaire Research Lab with Shell Development Company, Houston, Texas.



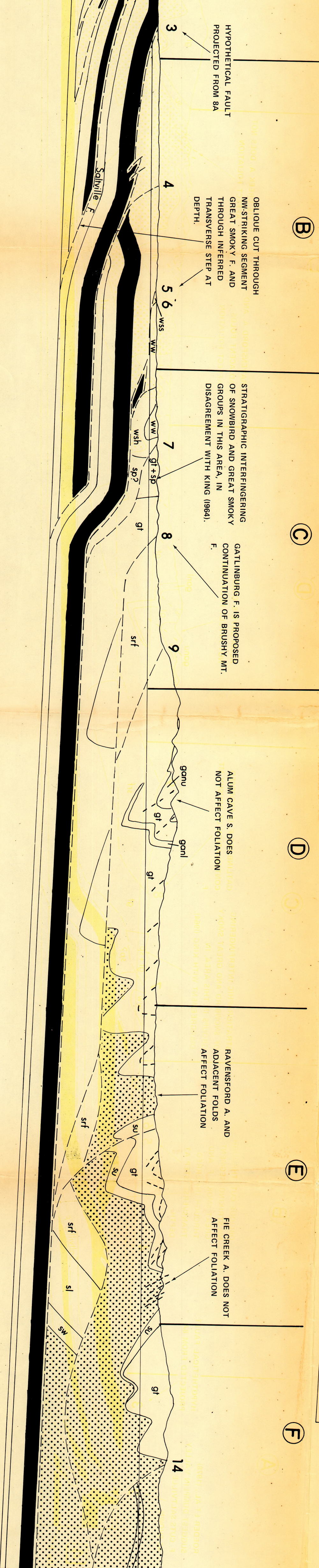
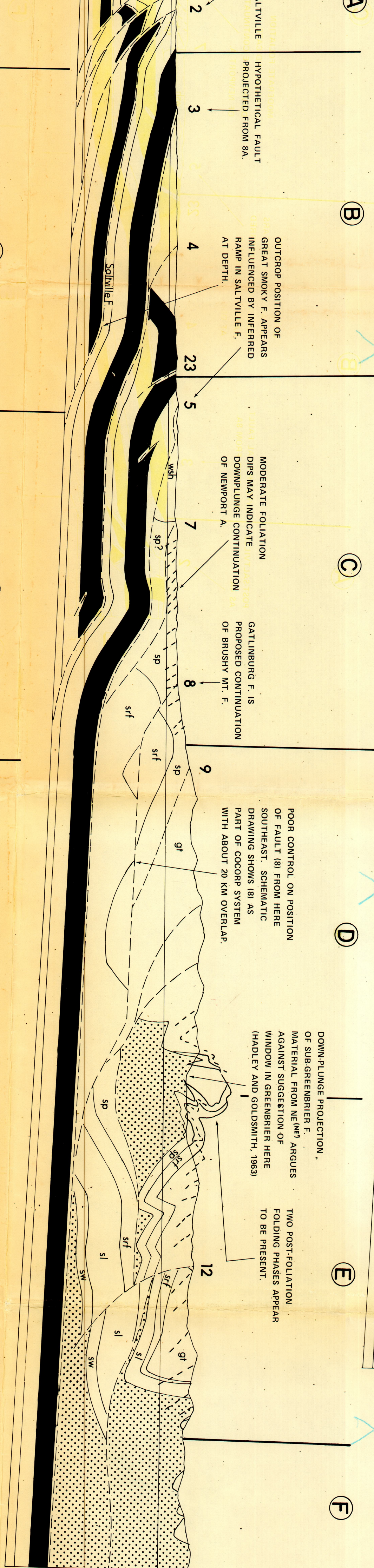
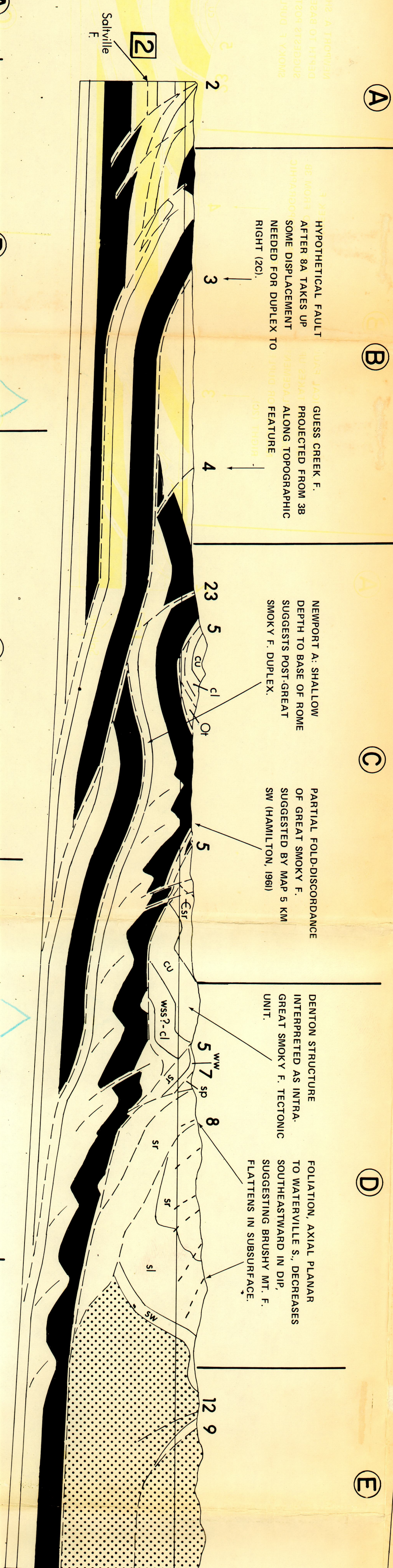
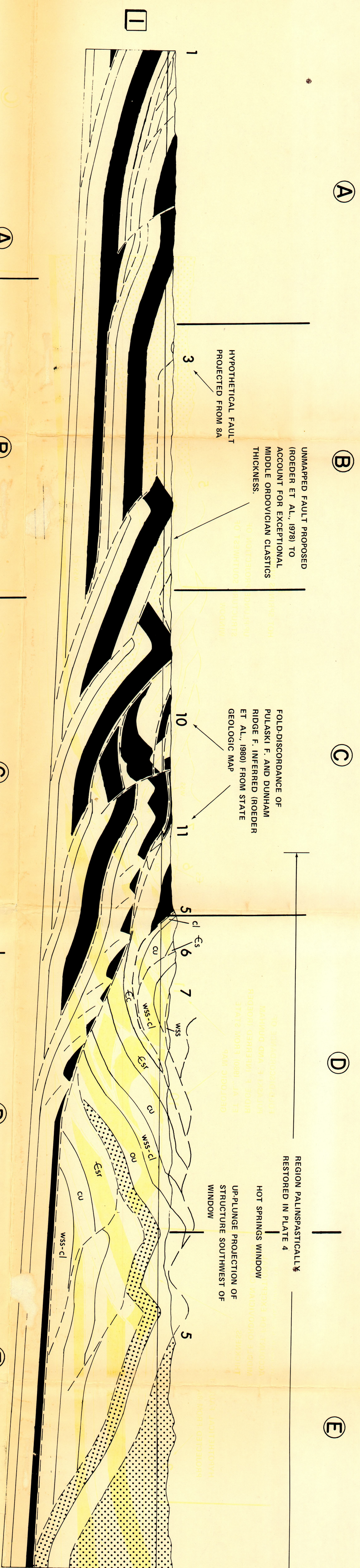


PLATE I  
STRUCTURE SECTIONS  
1 - 4







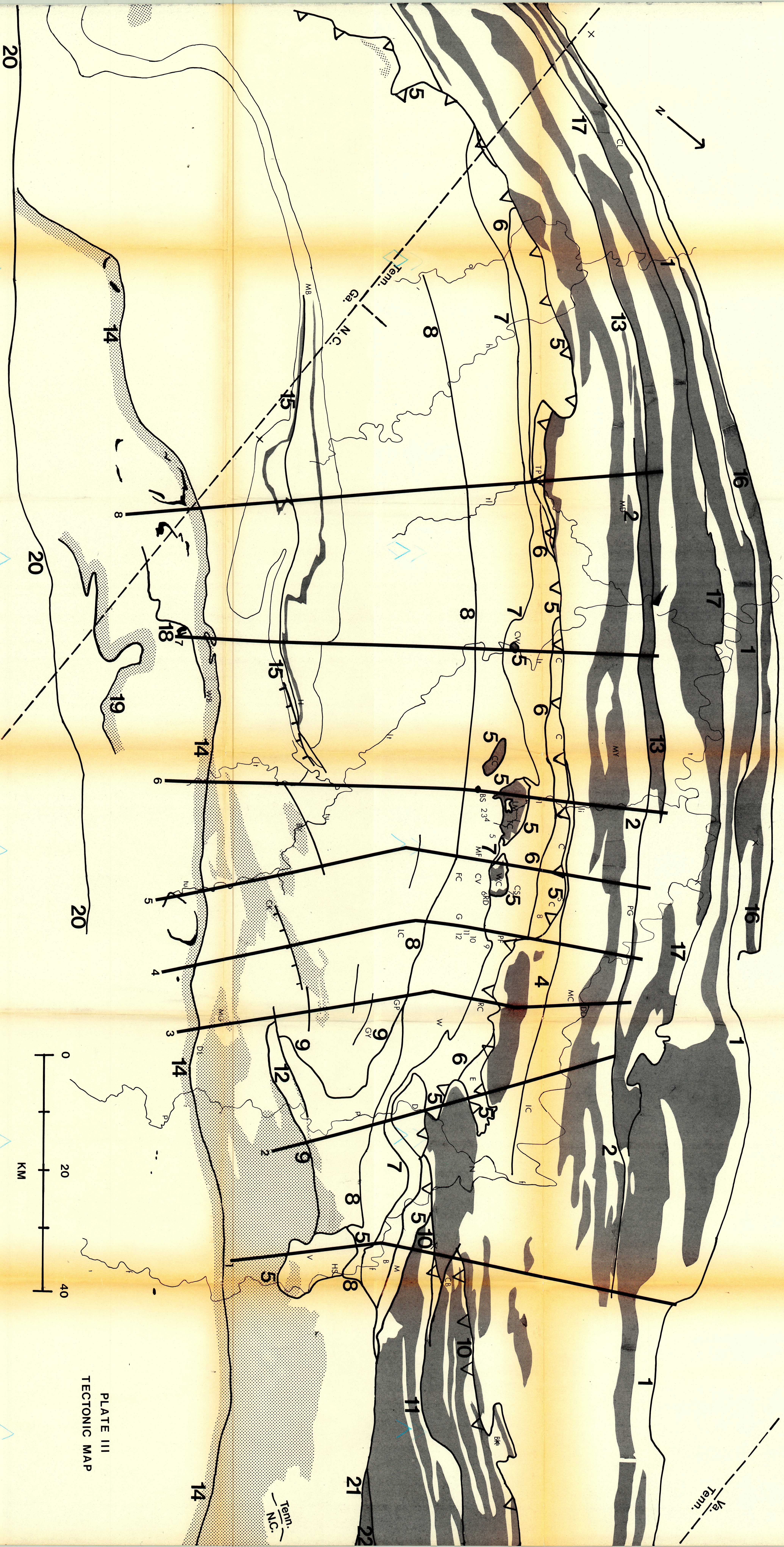


PLATE III  
TECTONIC MAP





PLATE IV  
 RESTORATION OF PART OF SECTION I



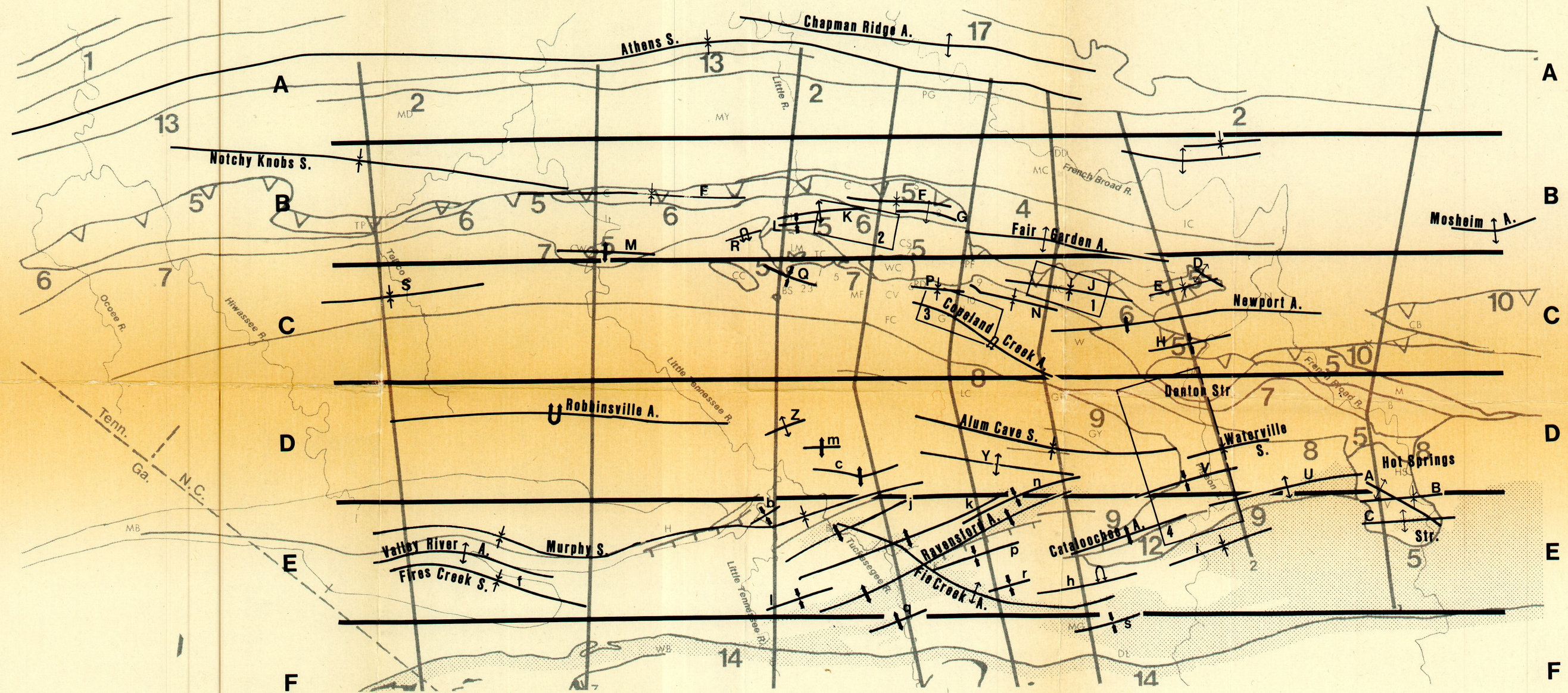


PLATE V  
REFERENCE DIVISIONS  
AND MAJOR FOLDS

